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WORLD'S BIGGEST CLEANING JOB *

BY

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Ladies and Gentlemen, I am pleased to participate in the lecture-demonstration series "Science is Fun" and have the opportunity to make my first public remarks on the subject of air pollution in my own town of Philadelphia.

We hope to interest you with our demonstration. Personally may I express the wish to leave with you a very serious message.

Air pollution means injury to health and damage to property in every populated section of our modern world. In such places, scientists have carefully determined that the main components of polluted air are carbon monoxide, hydrocarbons and derivatives produced by incomplete combustion. Beside these, sulfur oxides, calcium, lead, etc., are also found—but in very minor quantities.

The major sources of hydrocarbons and carbon monoxide are: automobile exhausts, incinerators, open fires, fuel-oil burners, vapors from industry—with the automobile being the largest contributor.

At least one million eight hundred thousand pounds of hydrocarbons, plus ten million pounds of carbon monoxide, are delivered daily by automobiles and trucks to the atmosphere of Los Angeles. Many days of the year such conditions make living very unpleasant.

Air pollution affects everybody and, considering the sources, is everybody's responsibility.

From my experience in dealing with industry, I gather that it will continue to do its part. However, this will only alleviate a minor part of the danger. It is consequently imperative that the public be fully informed so that it can demand other corrective measures.

* Adapted from the "Science Is Fun" lecture, sponsored by the Membership Department of The Franklin Institute, Wednesday, May 12, 1954, and delivered in the Lecture Hall of the Institute.

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(Note—The Franklin Institute is not responsible for the statements and opinions advanced by contributors in the JOURNAL.)

Over fifty years ago high incidence of skin cancer was found among London's chimney sweeps. In 1912, Doctors W. C. White and C. H. Marcy, in a study made in Pittsburgh, discovered that in certain areas where there was more soot, the death rate by pneumonia was correspondingly higher. More recently, Dr. Clarence A. Mills after extensive research in Cincinnati, Chicago and Detroit, revealed that death rates from pneumonia, tuberculosis and cancer of the lungs were higher where pollution was greater.

It would take too much time here to discuss all the aspects of this complicated problem, and so I will confine myself briefly to the danger of the automobile exhaust, which is the major offender.

This danger was recognized as early as August 4, 1923, when, in the American Medical Association *Journal* two scientists of vision—Doctors Henderson and Haggard, of Yale—said:

> The exhaust gas of automobiles is extremely poisonous. Positive protection for the public and removal of danger for the careless individual are needed. In fuel there is often a high content of benzene and related substances. The vapor of benzene is now recognized as one of the most harmful. Its effects are cumulative and progressive, resulting in anemia, nervous disorders, and probably tuberculosis.

Then, in December 1953, Dr. Paul Kotin, working at U.C.L.A. under a grant of the United States Government, made the startling announcement that extracts from the Los Angeles air caused cancer. The results obtained on animals, using extracts from the air, were *almost identical to the results obtained when using extracts taken directly from automobile exhaust gas.* I met Dr. Kotin in 1952—exactly a year before—and he told me of his experimentation, and it is my humble opinion that his findings deserve the most careful attention of our country's highest authorities—because long before Dr. Kotin's statement, chemists had published the following facts which substantiate his findings.

Dr. Fieser, now of Harvard, since the twenties, has synthesized or purified, usually by crystallization, a long list of organic compounds that he proved to be carcinogenic—that is, capable of inducing cancer in living cells. Some of those organic compounds are products of incomplete combustion and are found in coal fires, automobile exhausts, oil burners, etc.

Members of the Institute will certainly remember Dr. Stanley, of world fame, and a medalist of the Institute, when he told us of his discovery that the influenza virus is not a living organism, but a crystal. Many of the carcinogenic compounds synthesized by Dr. Fieser and others, are crystals, and may well be cancer virus. We breathe them in the air—and we swallow them. Moreover, they invade the shops in our streets, settle on our food, from which they are difficult to remove because they are not water soluble.

More simply, we all know that our buildings are blackened, our clothes soiled, vegetation ruined—and to me, as an engineer, it does not stand to reason to expect delicate human tissues to be more resistant than stone. And, as an engineer, I am confident that we can get rid of this menace if we want to. It may seem impossible; however, by applying catalysts to the sources of the smoke and carbon monoxide, it becomes rather a simple matter.

Catalysts transform very easily, at low temperatures, hydrocarbons and carbon monoxide into water and carbon dioxide, which is the composition of sparkling water. This could also be done without catalyst—by heating the fumes to white heat—but this is obviously impractical.

While I do not believe that people should consider catalysis a mystery, I have found it impossible to define what a catalyst is in layman's terms. I can say that catalysis is a phenomenon of chemistry—in fact, catalysis is a chemistry of intermediate compounds. Consequently, catalysts are chemicals. I will say further that catalysts enter the chemical reaction, are the main factor in the reaction, and possess the ability to revert to original state after the reaction is accomplished.

Starting in France in 1923, and with the help since 1930 of a brilliant staff of chemists and engineers in the United States at the Houdry Process Corporation, Sun Oil Company, and Oxy-Catalyst, Inc., we have made together thousands of different types of catalysts, and tried them in hundreds of thousands of experiments. Only a handful of those catalysts have reached industrial stage, in catalytic cracking, synthetic rubber, catalytic reforming, and oxidation of waste gases.

The performance is best shown through actual demonstration, and I would like now to turn you over to J. W. Harrison, who is Director of Research at Oxy-Catalyst. Mr. Harrison was the first chemical engineer assigned to work with me when I arrived in this country at the end of 1930—and he has played an important and devoted part in all our development work and laboratory studies.

DEMONSTRATION OF CATALYSTS AND DEVELOPMENTS FOR AIR POLLUTION CONTROL **

Demonstrations

Oxycat

The Oxycat (Fig. 1) is our first commercial oxidation catalyst to be developed. It is made up of two porcelain end plates which hold in place 71 porcelain rods. These rods are coated with a catalyst composed

** This section of the lecture-demonstration was in charge of Mr. Harrison, who demonstrated and explained the different types of oxidation catalysts and catalytic devices developed by Mr. Houdry and his engineers for the purpose of cleaning the air in our factories, industrial areas, streets and homes. The demonstrations herein described were performed in the Lecture Hall.

of platinum and aluminum. The Oxycat—5½ in. long, 3 in. wide and 3 in. high—is very sturdy and compact in its construction. The porcelain used is a spark plug type, highly resistant to both thermal shock and mechanical stress. Catalytic reaction occurs when the combustible gases come in contact with the surface of the catalyst. The rods are tear-drop in design to obtain a maximum catalyst surface and to minimize the resistance to the air flow directed through the Oxycat, with the rounded end of the tear-drop design facing the flow.

To demonstrate the principle of catalytic reaction, a mixture of

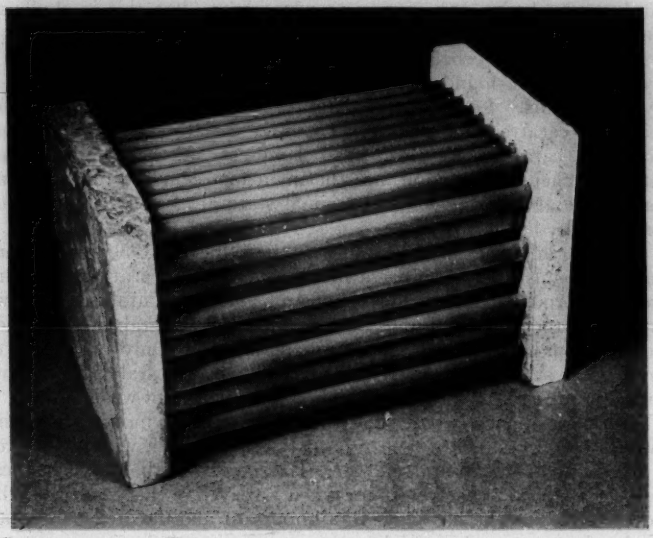

FIG. 1. The Oxycat.

city gas and air was passed through two Oxycats installed in series. Using a Bunsen burner, the catalyst was preheated to a temperature of 500° F., which is the temperature at which the reaction starts. The flame was put out and the gas was allowed to pass through the unit and the catalytic reaction started. Soon thereafter the catalyst was glowing to red heat due to the exothermic reaction which takes place when combustible gases come into contact with the catalyst. The combustion of the gas to carbon dioxide and water vapor was complete as the gases out of the catalyst could not be ignited nor would they support combustion.

OCM Muffler

The first use of the Oxycat was in conjunction with gasoline engines for the elimination of carbon monoxide and hydrocarbons. Using a cut-away model of an OCM Muffler (Fig. 2), Mr. Harrison explained the construction and the operation of the apparatus. This device consists of multiple Oxycat units enclosed in individual metal boxes which are bolted together. The number of units used is dependent on the size of the engine. At the inlet of the catalytic sections, a Venturi admits into the system the amount of fresh air necessary to complete

FIG. 2. OCM muffler, cutaway model.

the combustion of the gases to CO_2 and H_2O. This is necessary because the exhaust gases as they come out of the engine do not contain sufficient oxygen to complete the combustion.

The main use for this apparatus is for industrial gas trucks used inside of plants and warehouses. There are several thousand such units in operation throughout industrial plants in the United States. A Baker-Raulang gas lift truck (Fig. 3) was driven into the hall to demonstrate the effectiveness of the apparatus. With the engine running, the exhaust was free of carbon monoxide and obnoxious odors.

This invention is permitting the use of gasoline-powered machines in enclosed and poorly ventilated areas, such as cold-storage rooms, warehouses, shops, etc., and has made the use of such machines safer for inside use.

Leaded Muffler

This apparatus works on the same principle as the OCM Muffler for industrial trucks. It has been designed, however, for automobiles.

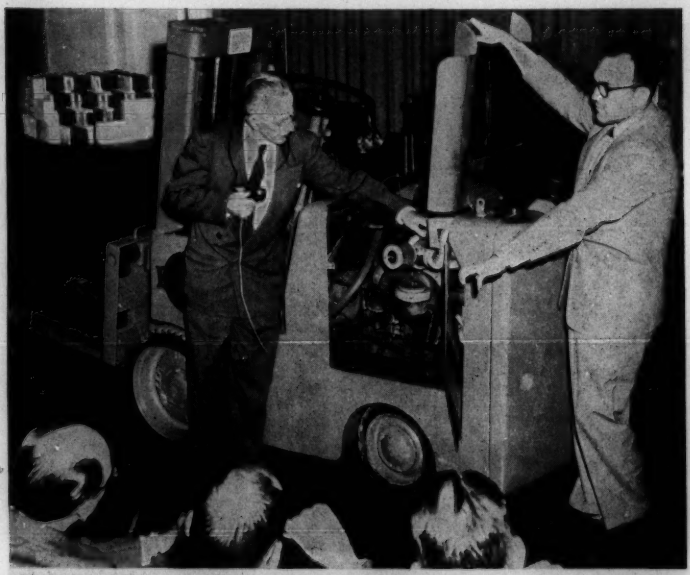

FIG. 3. Baker-Raulang truck equipped with OCM muffler.

Its size is approximately the same as a standard muffler and it can be installed just as easily. It operates on all types of fuel, whereas the OCM Muffler functions only on unleaded gasoline which is a gasoline that does not contain tetra-ethyl lead. This new development, which is not in production as yet, will eliminate over 80 per cent of the hydrocarbons and 90 per cent of the carbon monoxide emanating from the exhaust. It has been subjected to exhaustive tests, including an extensive road test, under all operating conditions. This development will be made available to the public at a reasonable price when produced in large quantities.

"Dieseler"

The next apparatus to be shown was a new catalytic exhaust developed for diesel equipment. It is similar in construction to the OCM Muffler for gasoline engines. The main difference is that a Venturi is not required since the exhaust gases contain a sufficient amount of oxygen to complete the combustion of the hydrocarbons and carbon monoxide. This commercial apparatus is only available for 4-cycle engines at this time. It reduces 80 per cent of the obnoxious fumes and odors when an engine is operating at 60 per cent load. The main use at present is in conjunction with mining and construction equipment where fumes and odors are a major problem.

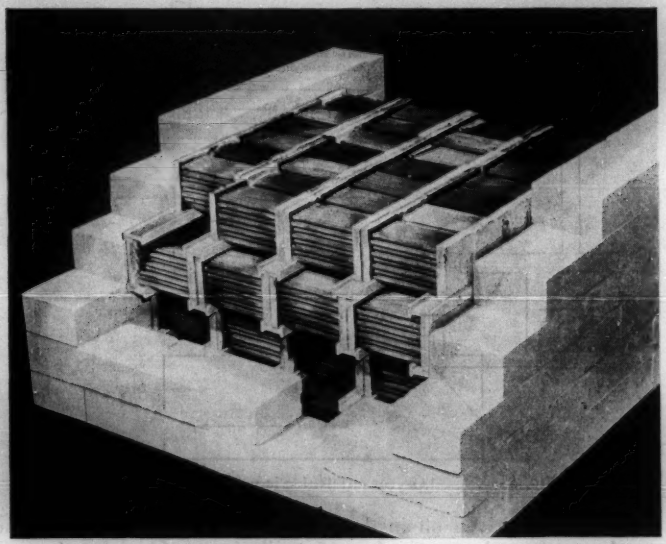

FIG. 4. Industrial installation of Oxycat.

Development work is continuing on this apparatus to extend its use to 2-cycle diesel engines and to make it practical for buses and other highway vehicles.

Industrial Applications

The Oxycat can also be applied to eliminate fumes and objectionable odors from industrial processes. Oxycats can be stacked side by side, one on top of another, in any quantity, depending on the size of the installation (Fig. 4). Installations are usually made in the exhaust stack of the industrial process. The Oxycat can be effectively applied

to all processes emitting hydrocarbon or other combustible fumes to the atmosphere. Some current applications are:

(*a*) Petroleum industry—for asphalt processing and oil refining;
(*b*) Incinerators;
(*c*) Food processing, such as fish drying, meat rendering, and coffee roasting; and
(*d*) Industrial drying ovens and furnaces. A typical installation would be for a paint drying oven (Fig. 5).

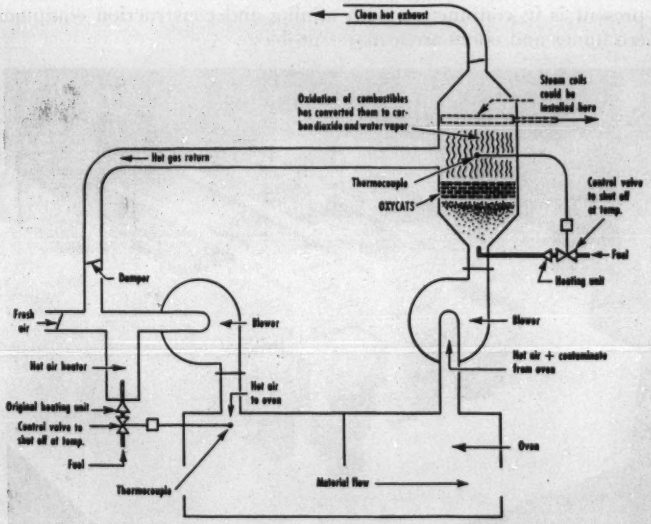

FIG. 5. Typical Oxycat installation in paint-drying oven.

The solvents driven off in drying are normally exhausted to the atmosphere, often the cause of an air pollution problem for the surrounding community. By installing the Oxycat in the exhaust system, the solvent vapors are readily oxidized to CO_2 and H_2O which, of course, are odorless and safe. The heat given off by the reaction can often be used by different methods:

(1) It can be directed back into the oven proper, thus considerably reducing or, in some instances, completely eliminating the need for an outside source of fuel for heating the oven;
(2) The heat can be used for other processes in the plant; or
(3) By installing steam coils after the catalyst, usable steam can be made.

Industrial installations often pay for themselves through heat recovery. For fuel economy, some industrialists even install Oxycats when there is no pollution problem.

Applications for the Home

For home use another type of catalyst has been developed which consists of resistance wire coated with a platinum catalyst similar to the coating of the Oxycat. This catalyst has the ability to function at low temperatures. It eliminates cigarette smoke, undesirable odors

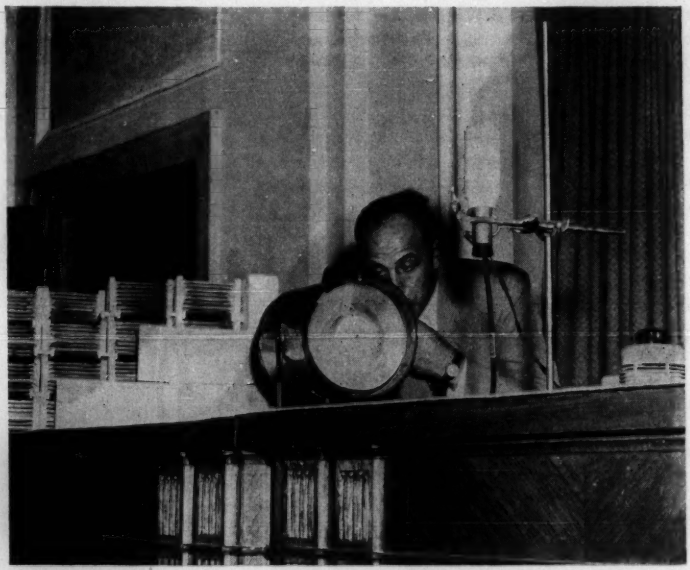

FIG. 6. Cigarette smoke being blown through a room air purifier.

from cooking, hospitals, etc. It is also effective for the elimination of pollen and bacteria.

The effectiveness of this catalyst was demonstrated using an experimental apparatus very similar in appearance and construction to a commercial electric heater and ventilator. Cigarette smoke passing through the apparatus (Fig. 6) is completely eliminated. The same experiment was run using small circular wire coils coated with this catalyst and installed in a small chimney approximately 8 in. high and 2 in. in diameter. Again it was shown that cigarette smoke was completely removed.

This catalyst has been thoroughly tested and is ready for commercialization. Several commercial applications are being developed at this time.

Gas-Fired House Incinerator

The Oxycat has also been applied to the much publicized house incinerator. This new gas appliance is rapidly becoming one of the major gas appliances. The market has been restricted in certain areas due to smoke and odors emitted from this device. This problem has

FIG. 7. House incinerator.

been resolved by installing Oxycats in a secondary chamber at the exhaust part of the incinerator. A small gas burner provides the necessary heat for the catalyst.

A commercial incinerator, installed in the Lecture Hall, was actually operated all during the demonstration (Fig. 7). The exhaust, which was directed into a hood to keep the products of combustion from the room, was completely free of smoke. When the door to the combustion chamber of the incinerator was opened, a large volume of smoke billowed out.

This concluded the demonstration.

CLOSING REMARKS BY MR. HOUDRY

You have seen different types of catalysts which have proven themselves capable of cleaning fouled air.

Last week the Air Pollution Control Association held its 47th Annual Convention, at which Gordon P. Larson, Director of the Los Angeles County Air Pollution Control District, was elected President. I have had the pleasure of working with Mr. Larson and his technicians for several years.

To control air pollution, Los Angeles has a budget more than twenty times larger than that of Philadelphia—although both cities are of same size in population. The effort of the Larson group has been considerable, and is leading toward success. Thanks to it we have known what to do and where to strike to win this fight. As far as we are concerned, it has been an inspiration in our work.

They were the first to be interested in a solution for the automobile exhaust—because they were the first to determine as accurately as can be done, the national importance of this danger.

They were also the first to search for solutions. At their request we sent the apparatus which you see now to Los Angeles—with our engineers and mechanics—where we did four full months of testing.

On April 15 of this year, Mr. Larson announced officially that the tests showed that our apparatus eliminated more than 80 per cent of the hydrocarbons atomized to the atmosphere by automobile engines.

We hope we have succeeded in interesting you with our explanation and demonstration of our work in the fight against air pollution, but if we have only made you more aware of the grave import of this problem, our time has not been wasted.

It has been a great pleasure to be here, and my thanks again to the Institute—and to you, Ladies and Gentlemen.

Semi-Automatic Self-Loading Shotgun.—The first semi-automatic shotgun that will stay on target shot after shot as fast as the trigger is pulled was unveiled recently by Winchester after 16 years of research. The new Model 50 is the world's first self-loading shotgun with a non-recoiling barrel and an independent chamber. The unique chamber moves less than one-tenth of an inch! This tiny movement not only actuates the breech bolt but also starts the entire cycle of unlocking, extraction, reloading and locking.

The recoil effect of the Model 50 is 20 to 30 per cent "softer" than other semi-automatics, said J. T. Boone, sales manager of the Arms and Ammunition Division of Olin Industries, Inc., makers of Winchester and Western sporting arms and ammunition.

Another result of the new design is that the aim-disrupting clatter and "double-shuffle" common to all self-loading shotguns have been entirely eliminated.

Oscillograph patterns show that the energy expended in recoil by the Model 50 travels to the shoulders from the chamber in a gradual pushing, rather than a punching action, Mr. Boone said. Thus the gun greatly decreases whatever tendency the shooter has to flinch. The combination of "soft" recoil and fixed barrel contributes to faster pointing and closer holding.

Although the Model 50 shoots as fast as the trigger can be pulled, the trigger design makes it impossible for the gun to go fully automatic.

The new gun may be taken apart and assembled without tools of any kind. Even new barrels may be fitted by the owner; there is no need to return the gun to the factory for special machining.

All low and high base shotgun loads of the proper length and gauge may be fired without making any adjustments in the gun.

The barrel and receiver of the Model 50 are made of heat-treated chrome molybdenum Winchester-proof steel. Other critical parts, including the independent chamber, are of high alloy-heat-treated chrome vanadium steel. The hand-checkered pistol-grip stock and forearm are of American walnut finished in natural tones.

The Model 50 is available in field, trap or skeet grades with plain or ventilated rib barrels. The ventilated rib, which provides an unbroken sighting plane, is an unusual feature on a self-loading shotgun.

Electronic Aids for Fishing.—Fishing has indeed become a science with several New England fishermen who have equipped their vessels with Raytheon's "Fathometer"—an echo depth sounder. Use of this instrument enables the fisherman to locate the heaviest concentrations of fish. Two types of echo depth sounders are in use—sometimes on the same vessel. Both types send out sound signals through a transducer located beneath the vessel, and receive the returning echoes. A "recorder" reveals fish schools and bottom information on graph paper which can be stored for future; while an "indicator" provides the same information by means of a flashing light on a calibrated dial.

VERY LOW FREQUENCY NOISE POWER FROM THE LIGHTNING DISCHARGE *

BY

JOHN S. BARLOW,[1] GEORGE W. FREY, JR.,[2] AND JOHN B. NEWMAN[2]

SUMMARY

Following a summary of present knowledge of the lightning-discharge mechanism, the expression of Bruce and Golde for the destruction of the cloud-image dipole by the discharge has been derived phenomenologically. The radiation power spectrum of a lightning discharge has been calculated for two cases, considering the radiation to arise from (*a*) the destruction of the cloud-image dipole and (*b*) the channel as a linear antenna.

The power spectrum of the waveform of a distant daytime atmospheric (daytime "tweek") characterized by a decrease in both amplitude and instantaneous frequency with time, has been obtained, assuming exponential decay of a sinusoidal waveform whose frequency is that of the power-weighted mean frequency. This waveform power spectrum, the transformed results of the (*b*) analysis above (using available experimentally determined propagation data for very low frequencies), and one of Bowe's spectra of distant daytime atmospherics have been compared. There is reasonable agreement of the transformed discharge spectrum with the observed "tweek" spectra, despite the approximations of the calculations, the variations among individual discharges, and the interpolation and extrapolation of the propagation data. These results indicate a peak in the power spectra of distant daytime atmospherics at about 10 kc., in agreement with other "tweek" workers.

While the Bruce and Golde expression seems adequate for radiation analysis, a question has been raised concerning its use, except in special cases, for the near field analysis.

I. INTRODUCTION

A number of observers (1–16)[3] have studied the characteristics of the radiation field of lightning strokes. The complexities of the stroke phenomena and of ionospheric reflection are so great that an exact analysis has not yet been made. There are so few quantitative data available that it is not known, in most cases, how the waveform of the distantly propagated atmospheric results from the combined characteristics of the lightning stroke and the propagation medium.

The waveforms of atmospherics observed with wide band receivers have been termed "tweeks," because of components which are present in the audio frequency range. The observed waveforms are of many different kinds (11–13, 15); there may be a series of recurrent pips,

* This work was partially completed in the Programs Research Unit, operating under Contract N6-onr-24311 of the Office of Naval Research.

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[3] The boldface numbers in parentheses refer to the references appended to this paper.

corresponding to successively larger numbers of reflections from the ionosphere of a short pulse, a single pulse similar to the above but without following reflections (night-time "tweeks"), a decaying quasi-sinusoidal wave with increasing period, or, finally, a decaying very irregular wave (daytime "tweeks"). The origins of some of these waveforms are considered in more detail below.

The frequency analysis of lightning radiation is important for very low frequency communications because the peak of atmospheric noise power has often been stated (2, 6) to lie at about 10 kc. In this paper, the power spectra of a nearby cloud-to-ground flash and of a distant daytime atmospheric are computed. While for the nearby flash, it is necessary to include some assumption regarding the mode of the radiation along with observational stroke data, the power spectrum of the distant atmospheric is computed from its observed waveform only. The spectra are then compared using the available data on the attenuation of the propagation medium (9, 13, 16).

II. THE POWER SPECTRUM OF THE LIGHTNING DISCHARGE

While the basic mechanism of the lightning discharge can be explained, knowledge of the charge and current densities involved is still inadequate for a complete calculation of the radiated energy. From a summary of the knowledge of the discharge mechanism, two models for the radiating system are assumed and their power spectra calculated and compared.

A. The Stroke Mechanism

A complete cloud-to-ground discharge through previously un-ionized air usually consists[4] of the following: (1) a pilot streamer, which is a negative discharge, propagated from cloud to ground with a relatively low velocity (10^7 cm./sec.) and whose presence is inferred since it has never been directly observed, (2) a stepped streamer, also negative, propagated from cloud to ground, but with a discontinuous velocity (10^9 cm./sec.) so that it overtakes but never exceeds the pilot leader, and (3) a positive return streamer, propagated from ground to cloud with a velocity of about one third that of light. The current in the return streamer has been measured in several ways (5), and it is known to have been as high as 218 kiloamperes (18). The stepped and return streamers have been observed in lightning throughout the world (5, 6, 17). The pilot streamer of the lightning discharge has never been photographed (19) although in the laboratory study of the long spark, photographic records show it preceding the stepped streamers (17, 20).

[4] There is considerable evidence (5, 17) to indicate that the majority of cloud-to-earth discharges originate from negative charge centers in the cloud. Only about 65 per cent of this majority are of the type discussed above. See Loeb (17) for discussion of the second type.

Repeated flashes occur along the ionized channel of the initial flash at intervals of about ten milliseconds or longer. An initial discharge is followed on the average by three successive discharges, although as many as forty have been observed in a single channel. In the repeated discharge a single streamer, the dart streamer, propagated with a high velocity (varying from about one three-hundredth to one-tenth that of light) replaces the pilot and stepped streamer of the initial discharge. Malan and Schonland (21) have shown that successively higher charge sources in the cloud are tapped by repeated flashes, and from their data, it seems reasonable that the repeated flash will carry successively smaller return current, although still within an order of magnitude of that in the initial return streamer.

During the last thirty-five years the continuing investigation of the lightning discharge and the laboratory study of the long spark at atmospheric pressure have led Schonland, Raether, Loeb and Meek to propose and develop the streamer-avalanche mechanism (17, 22, 23). For the negative discharge the mechanism consists of two negative initiating streamers, a pilot and a stepped streamer, followed by a high current, high velocity positive return streamer. The radii of the pilot and stepped streamers (about one-half meter and about one centimeter respectively), the minimum pilot current (0.1 amp.), the range of the stepped streamer current (50–500 amp.), the stepping regularity (from time of ion recombination), and the correct magnitudes for the streamer velocities may all be calculated from the streamer avalanche mechanism (17, 20, 23). The calculations agree rather well with the lightning and long spark data (17). A comparison of velocities, current densities, channel-field strengths and ratio of length to radius for lightning and the long spark leads to the conclusion that both are produced by the same mechanism (19). For this reason the pilot streamer in lightning is inferred (17, 19). However the repeated failure to observe the pilot streamer and any electrostatic field changes just previous to the main stroke (return streamer) has led Schonland (19) to propose a new explanation of the step process of the lightning discharge. In this proposal, "the broad pilot streamer," the pilot and the step streamers have the same diameter (2.5 meters) and carry the same current (modal value, 320 amp.). Moreover, Schonland suggests a transition in the discharge from the narrow avalanche (streamer-avalanche) to the broad pilot as the potential difference increased from 1 million volts to 3 million volts across the discharge gap. This transition is supported by the experiments of Hagenguth *et al.* (24) and Akopyan and Larionov (25). Most long spark experiments to date have been at potential differences below 1 million volts; on the other hand, lightning discharges occur at potential differences considerably in excess of 3 million volts (5). While the streamer-avalanche mechanism seems firmly established (17) for both positive and negative discharges, there is some evidence (26) that raises questions about the positive discharge.

The current waveforms in return streamers are obtained from oscillographic records of the current resulting from a direct stroke of lightning to steel balloon cables, overhead transmission lines and steel towers. These waveforms are certainly influenced by the response characteristics of the struck systems. This question has been considered (27, 28) but not sufficiently to be included in a summary (5) of the data on the lightning discharge. This summary indicates that the waveforms are all similar in nature, yet it is remarked that the data are incomplete and often ambiguous.

For purposes of this analysis, the return stroke current waveform is approximated by the waveform of the current surge in an overhead

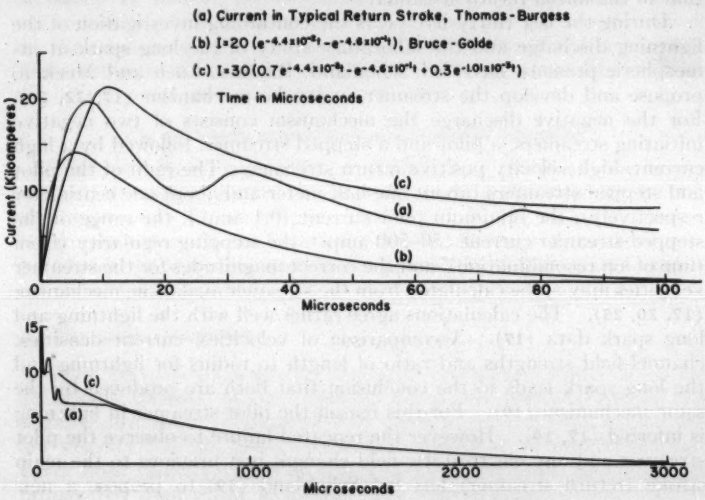

FIG. 1. Current in overhead line struck by lightning.

transmission line resulting from a direct strike. This waveform was taken from Bruce and Golde (5). Approximate expressions for the return current waveform may be written

$$i = i_0(ae^{-\alpha t} - be^{-\beta t}). \tag{1}$$

However, Fig. 1 shows this is sufficient only for the early behavior of the current. Three exponentials give a better fit over the complete duration of the current. Equation 2 gives the expression which will be used to approximate the transmission line current waveform here. Both expressions are plotted with the actual waveform in Fig. 1.

$$i = i_0(ae^{-\alpha t} - be^{-\beta t} + ce^{-\delta t}), \tag{2}$$

where $a = 0.7$, $b = 1$, $c = 0.3$, $\alpha = 4.4 \times 10^{-2}$ μsec^{-1}, $\beta = 4.6 \times 10^{-1}$ μsec^{-1}, $\delta = 1.01 \times 10^{-3}$ μsec^{-1}, and $i_0 = 30$ kiloamperes; the constants a, b, c, δ, i_0 have been obtained by fitting Eq. 2 to Fig. 1(a); α and β represent average discharge behavior (5). An expression such as Eq. 2 is necessary to include in the analysis the contribution of the long, slowly decaying tail of the current waveform. From inspections of the half periods of the oscillatory components of the current waveform, Fig. 1, important contributions to the power spectrum might be expected in the approximate range 25 kc. to 40 kc., above the range of principal interest here.

Observations of the velocity of the return streamer show that it has a time dependence of the form (5, 6)

$$v = v_0 e^{-\gamma t} \tag{3}$$

where $v_0 = 8 \times 10^9$ cm./sec. and $\gamma = 3 \times 10^{-2}$ μsec^{-1} as "average" parameters (5). The initial velocity and its decay in time are both consistent with the streamer-avalanche mechanism (22, 29). The average data for v_0 and γ are out-dated since Eq. 3 with these values only allows a maximum height of 2.7 km. for the return streamer. This is much lower than the currently reported modal value of 5 km. (19, 21) for the first discharge channel and similarly these data cannot accommodate repeated discharge data (21). However, no recent modal value for γ is known.

The theory of the streamer-avalanche mechanism includes a calculation of minimum currents required to sustain the pilot and stepped streamer processes (22, 23). Presumably maximum currents vary with the initial conditions in the individual case. The heavy return streamer is complicated by a number of factors which make a quantitative evaluation of its current very difficult. There are inadequate data on the distribution of the cloud charge by pilot and stepped streamers. Branching and fine structure (6, 30) of the lightning discharge indicate the wide variations with individual strokes and difficulty of handling analytically any but an ideal case. Some data (19, 31) are available on the diameter of the return streamer; it is known to be smaller than that of broad pilot channel due to magnetic constriction (19, 32) of the current. Certainly the current waveform results from a voltage pulse propagated like a travelling wave up the channel (33), neutralizing the charge left in the channel by the initiating processes and the remaining charge in the cloud. There are data to indicate the former to be about 60 per cent of the total (19). Ion-electron interactions in the channel (34, 35), percentage overvoltage (36) in the cloud-to-ground gap, and variation in earth resistivity (37) are additional complicating factors. No effort is made here to calculate the return current or even to approximate it, and only parts of the above summary are pertinent to support the assumptions made concerning the modes of radiation.

The above data serve as a basis for the analysis of the radiation from a nearby flash; whatever justification this procedure has must come from a comparison of the results obtained here, including propagation effects, with the observed radiation.

While the cloud-to-cloud discharge may provide more atmospheric noise power because of its greater frequency of occurrence, its analysis is beyond the scope of this paper. In the cloud-to-cloud discharge, the stepped leader is the dominant power stroke since the high cloud resistance prohibits a return stroke. M. M. Newman, using a circuit analog of the stepped leader, found a peak power at 12.5 kc. for a cloud-to-cloud discharge (38).

B. Radiation from the Destruction of the Cloud-Image Dipole

The first analysis of the radiation from the return stroke is based on an expression for the change of an electrical dipole moment, M, of the cloud charge and its image in the earth. This change results from a current i_t in the return stroke whose tip advances with a velocity v_t, where the current below the tip is assumed uniform at any instant. Bruce and Golde (5) state that the change of the moment is given by

$$dM = 2i_t dt \int_0^t v_t dt \tag{4}$$

since they were able to calculate from it the "near" magnetic field changes which agree well with Norinder's measurements (39).

The derivation of Eq. 4 is not clear since the change of a dipole moment resulting from the cloud charge and its image would involve two terms, one proportional to the change of the charge magnitude and the other to the change in separation of the charge and its image. The assumption that the return stroke provides an "effective neutralization charge per unit channel length" permits a straightforward derivation of the change of the moment, perhaps different from that used by Bruce and Golde. Let such a "neutralization charge" be given by

$$\sigma_{\text{Neutralization}} = \frac{i_t}{v_t} = \frac{i_0}{v_0}\left(ae^{-(\alpha-\gamma)t} - be^{-(\beta-\gamma)t} + ce^{-(\delta-\gamma)t}\right).$$

The cloud-image moment $\vec{m}(t)$ is then:

$$\vec{m}(t) = \vec{m}_0 - 2\int_0^{z(t)} \sigma_{\text{Neutralization}} \vec{z}\, dz \tag{5}$$

where $\vec{m}_0$ is the dipole moment at the instant the return stroke is initiated, $\vec{z} = \int_0^t \vec{v}_t dt$ and $dz = v_t dt$. It should be clear that this "neutralization charge" is a hypothetical quantity chosen for calculation

purposes, for it is known that the electron and ion velocities in the channel are very much less than v_i (22, 29).

The electric field of a dipole of moment $\vec{m}$ at a distance r in an equatorial plane is

$$\vec{\mathcal{E}} = \frac{\vec{m}}{r^3} + \frac{1}{cr^2}\frac{d\vec{m}}{dt} + \frac{1}{cr}\frac{d^2\vec{m}}{dt^2} \tag{6}$$

where c is the velocity of light. The third term, proportional to $1/r$ gives the radiation component of $\vec{\mathcal{E}}$. The radiated power spectrum of

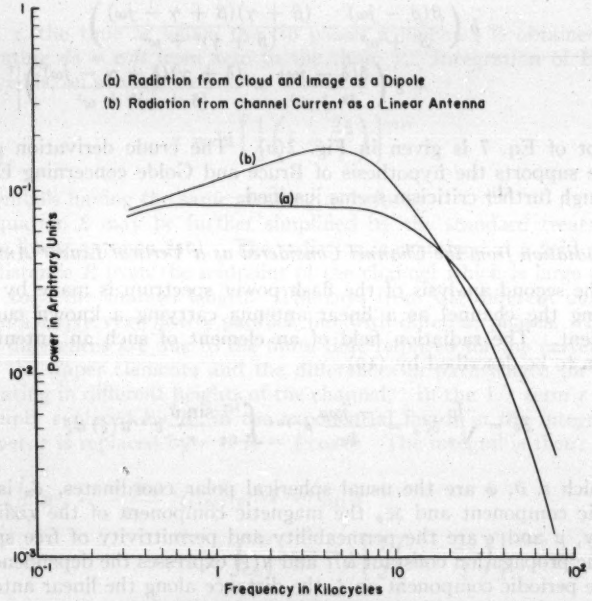

FIG. 2. Radiated power as a function of frequency from a lightning discharge neglecting propagation effects.

a flash, assumed to result from the destruction of the cloud-image dipole, is proportional to the product of the complex Fourier transform of $d^2\vec{m}/dt^2$ and its conjugate. Thomas and Burgess (6) used this fact, Eq. 4 and a two-exponential approximation of the current waveform (Eq. 1) to calculate the atmospheric noise power in the frequency region of 1–30 megacycles per second for this type of discharge. The same procedure is followed here with Eqs. 2 and 5, assuming also that the current has no spatial dependence.

It is readily shown that Eq. 5 leads to Eq. 4 except for a difference in sign which accounts for the destruction of the moment. Then $d^2\vec{m}/dt^2$ from either equation results in the same radiated power spectrum. The growth in length of the return stroke and the time dependence of the current are accounted for in this result. The power spectrum is proportional to

$$\left|\int_0^\infty \frac{d^2\vec{m}}{dt^2} e^{-j\omega t}\,dt\right|^2 = I_0^2 z^2_{\max.}\left|a\left(\frac{\alpha(\alpha-j\omega)}{\alpha^2+\omega^2} - \frac{(\alpha+\gamma)(\alpha+\gamma-j\omega)}{(\alpha+\gamma)^2+\omega^2}\right) - b\left(\frac{\beta(\beta-j\omega)}{\beta^2+\omega^2} - \frac{(\beta+\gamma)(\beta+\gamma-j\omega)}{(\beta+\gamma)^2+\omega^2}\right) + c\left(\frac{\delta(\delta-j\omega)}{\delta^2+\omega^2} - \frac{(\delta+\gamma)(\delta+\gamma-j\omega)}{(\delta+\gamma)^2+\omega^2}\right)\right|^2. \quad (7)$$

A plot of Eq. 7 is given in Fig. 2(*a*). The crude derivation given above supports the hypothesis of Bruce and Golde concerning Eq. 4, although further criticism seems justified.

C. Radiation from the Channel Considered as a Vertical Linear Antenna

The second analysis of the flash power spectrum is made by considering the channel as a linear antenna carrying a known current transient. The radiation field of an element of such an antenna is known to be described by (40)

$$\mathcal{E}_\phi = \sqrt{\frac{\mu}{\epsilon}}\,\mathcal{H}_\phi = \frac{-j\omega\mu}{4\pi} e^{-j\omega t}\int_{-l/2}^{l/2} \frac{\sin\vartheta}{r} e^{jkr} u(\xi)\,d\xi \quad (8)$$

in which r, ϑ, ϕ are the usual spherical polar coordinates, $\mathcal{E}_\phi$ is the electric component and $\mathcal{H}_\phi$ the magnetic component of the radiated energy, μ and ϵ are the permeability and permittivity of free space, k is the propagation constant ω/c and $u(\xi)$ expresses the dependence of a time periodic component on ξ, the distance along the linear antenna measured from its midpoint and l is the length of the whole antenna, in this case the channel in which the return current flows. Equation 8 gives the radiated field component of a particular frequency. Two additional considerations are necessary: first, the current is a transient and therefore its frequency spectrum is a continuous function of frequency given by

$$G(\omega) = \int_0^\infty i_0(ae^{-\alpha t} - be^{-\beta t} + ce^{-\delta t})e^{-j\omega t}\,dt = i_0\left(\frac{a(\alpha-j\omega)}{\alpha^2+\omega^2} - \frac{b(\beta-j\omega)}{\beta^2+\omega^2} + \frac{c(\delta-j\omega)}{\delta^2+\omega^2}\right). \quad (9)$$

Hence the current at a particular frequency would be given by

$$i_\omega(t) = u(\xi)e^{j\omega t}. \tag{10}$$

The function $u(\xi)$ contains the amplitude function, continuous in frequency, and a phase term which accounts for the delay in the radiation from the higher current elements consistent with the propagation of the stroke up the channel. It is given by

$$u(\xi) = |G(\omega)|e^{j\omega t}, \tag{11}$$

where τ, the time at which the tip passes a height ξ is obtained by integrating $dz = v\,dt$ from zero to the time, τ. Integration of Eq. 2 then yields, on solving for τ

$$\tau = \ln\left[\frac{1}{2}\left(1 - \frac{2\xi}{l}\right)\right]^{-1/\gamma} \tag{12}$$

the symbols having the same meaning as before.

Equation 8 may be further simplified by the standard treatment for the linear antenna (40). The radiation is examined at a field point at a distance R from the midpoint of the channel which is large compared to l, the channel length. The rays from the different current elements arrive very nearly parallel, but with different phases. These phase differences are due to the finite time required for the current to reach the upper elements and the differences in path length for rays originating in different heights of the channel. In the $1/r$ term r may be simply replaced by R; in the exponential factor in the integrand, however, r is replaced by $r = R - \xi\cos\vartheta$. The integral is then:

$$\mathcal{E}_\vartheta = \sqrt{\frac{\mu}{\epsilon}}\,\mathcal{H}_\phi = \frac{-j\omega\mu}{4\pi}|G(\omega)|e^{j(kR-\omega t)}\sin\vartheta \times \int_{-l/2}^{l/2} e^{-jk\xi\cos\vartheta}\left[\frac{1}{2}\left(1 - \frac{2\xi}{l}\right)\right]^{-j\omega/\gamma} d\xi \tag{13}$$

which is readily integrable for the equatorial plane, $\vartheta = \pi/2$.

The power spectrum is then given by:

$$\tfrac{1}{2}(\mathcal{E}_\vartheta\mathcal{H}_\phi{}^*)_{\vartheta=\pi/2} \sim \mathcal{E}_{\pi/2}\,\mathcal{E}_{\pi/2}{}^*.$$

The result is plotted in Fig. 2(*b*).

The spectrum from the first analysis is flat on the low frequency end and drops 10 db. at 55 kcs. For the second analysis there is a distinct peak at 4.5 kc., 3 db. above the low frequency end, and down 10 db. at 32 kc. Strong attenuation due to propagation at around 1–5 kc. obscures the differences between the two spectra at the lower

frequency end. A correction for the initial oscillatory component of the current waveform (Fig. 1(*a*)) would be expected to result in a less rapid decrease in the power spectrum in the frequency range of approximately 25–40 kc. for both analyses.

III. ANALYSIS OF A DAYTIME "TWEEK"

The "received" waveform, the typical distant daytime "tweek" as observed by Kessler and Goyder (12) using a wideband receiver (0–200 kc.), is now considered. The particular waveform, shown in Fig. 3, chosen for its regularity to facilitate analysis, is characterized by an exponential decay of amplitude and an increase in period with time. It may thus be described approximately by

$$E_t = E_0 e^{-At} \sin\left[2\pi\left(\frac{t}{T_0 - T_1 e^{-Ct}}\right)\right], \tag{14}$$

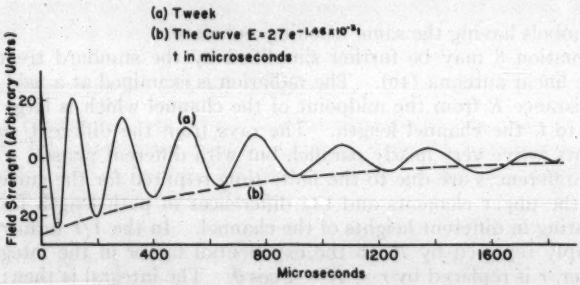

FIG. 3. Typical observed distant daytime tweek after Kessler and Goyder (radiation from distant lightning discharge).

where E_0, A, C, T_0, T_1 are constants.

To simplify the calculation, variation of the nominal period with time is neglected; instead,

$$E_t = E_0 e^{-At} \sin\,(2\pi t/T_m) \equiv E_0 e^{-At} \sin\,(Bt) \tag{15}$$

is used for analysis, where $B = 2\pi/T_m$ and T_m is the power-weighted mean period

$$T_m = 2\,\frac{\sum_{i=1}^{14} T_i (E_i)^2}{\sum_{i=1}^{14} (E_i)^2}$$

for the fourteen half periods of Fig. 3. T_i is the half-period corresponding to E_i.

The frequency spectrum is then

$$F(\omega) = \int_{-\infty}^{\infty} E_t e^{-j\omega t}\, dt \tag{16}$$

$$= E_0 \int_0^{\infty} e^{-At} \sin (Bt) e^{-j\omega t}\, dt \tag{17}$$

$$= \frac{E_0 B}{A^2 + B^2 - \omega^2 + 2j\omega A} \tag{18}$$

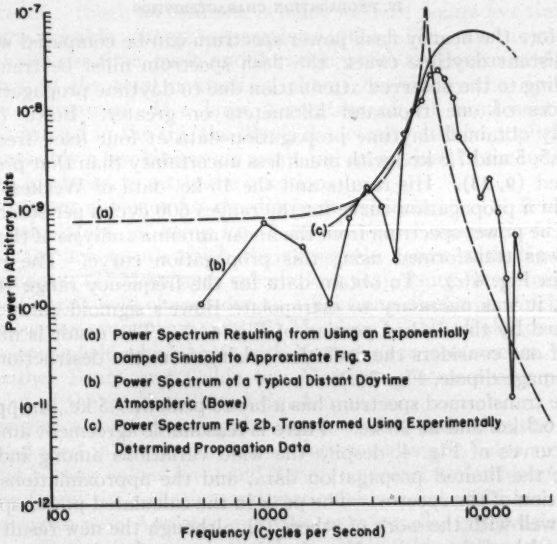

FIG. 4. Power spectra of radiation from lightning discharges.

and the power spectrum is

$$|F(\omega)|^2 = \frac{E_0^2 B^2}{[(A + j\omega)^2 + B^2][(A - j\omega)^2 + B^2]} \tag{19}$$

For the waveform of Fig. 3, $A = 1.46 \times 10^3$ sec.$^{-1}$, $B = 2\pi/171$ (microseconds)$^{-1}$ = 36,750 radians/sec. The value of T_m in B (171 μsec) corresponds to a quasi-frequency of 5850 cycles. Equation 19 is plotted in Fig. 4(*a*).

It is seen from Fig. 4(*a*) that the power spectrum is flat in the frequency range 100–300 cycles per second; there is a peak (+20 db.) at the quasi-frequency (5850 cycles), followed by a very rapid drop with further increase of frequency. It is apparent that a correction for the variation of the nominal periods of the tweek with time would result in a broadening of the peak of the power spectrum. The calculated result agrees rather well with the results of Bowe (13), whose spectrum of a tweek also appears in Fig. 4(*b*). In obtaining the spectrum, Bowe used three methods of approximate integration. His tweek has a peak power at 6.5 kc.; he also calculated the spectrum of a second tweek which has a peak at 7.5 kc.

IV. PROPAGATION CHARACTERISTICS

Before the nearby flash power spectrum can be compared with that of a distant daytime tweek, the flash spectrum must be transformed according to the observed attenuation due to daytime propagation over distances of one thousand kilometers or greater. Bowe (16) has recently obtained daytime propagation data at four fixed frequencies (0.6, 3.5, 5 and 7.5 kc.) with much less uncertainty than that previously reported (9, 13). His results and the 16-kc. data of Weekes (41) are given in a propagation curve for the ranges 600 cycles per second to 16 kc. The power spectrum from the linear antenna analysis of the nearby flash was transformed using this propagation curve. The result is given in Fig. 4(*c*). To obtain data for the frequency range 16 kc. to 20 kc., it was necessary to extrapolate Bowe's sigmoid curve; this is indicated by the dashed portion of Fig. 4(*c*). The result is much the same if one considers the radiation arising from the destruction of the cloud-image dipole, Fig. 2(*a*).

The transformed spectrum has a broad peak at 9.5 kc., dropping 2.2 db. at 6.3 kc. and at 20 kc. There is reasonable agreement among the three curves of Fig. 4, despite the wide variations among individual flashes, the limited propagation data, and the approximations in the calculation of the spectra. The peak in the calculated power spectrum agrees well with the work of others (6), although the new result here is the breadth of the peak. No other data concerning the average width of the peak have come to the authors' attention.

Previously the authors have transformed the linear antenna analysis with earlier data of Bowe (13) extrapolated from 10 kc. to 14 kc., covering the range from 4 kc. to 14 kc., and with that of Gardner (9) covering the range from 4 kc. to 20 kc. Despite uncertainties in their propagation data and approximations made in their use, the results agree rather well, except for normalization factors, with Fig. 4(*c*). The transformed spectra using the two sets of Bowe's data are fairly consistent; the peak of the transformed spectra, using Gardner's data, occurs at approximately 11.5 kc., but it is somewhat narrower (being

down 2.5 db. at 9 kc. and 18 kc.) than the peaks obtained from the Bowe data.

V. DISCUSSION

Although another method for obtaining the expression of Bruce and Golde for the change in moment due to the destruction of the cloud-image dipole has been found, the dipole model should not be used indiscriminately. It is applicable only for field points at a distance large compared to the separation of the charge and its image. Since this depends on the charge distribution in the channel at the moment the return streamer is initiated on which there are few data, the field points should be at least forty to one hundred kilometers away to avoid all special cases. (Such an estimate is made for field points five times the maximum possible charge separation (21).) The return streamer current has a rise time, peak, and duration which are determined by the percentage of the total neutralized charge carried by the tip of the downward streamer. If a large percentage of the total neutralized charge is carried in the tip, the dipole model may still be applicable at field points only a few kilometers away, but an analysis of the individual discharge is needed to settle the question.

The present evidence for the dipole model includes: (1) Bruce and Golde's calculation (5) using Eq. 3, of the "near" magnetic field (inverse square law term) which they conclude agrees with Norinder's measurements; (2) Morrison's calculations (42), using Eqs. 4 and 6, of the total electric field change due to a lightning discharge which agree with his own measurements; and (3) Morrison's (42) calculations of the "near" electric field which agree with Norinder's measurements. However, neither Bruce and Golde nor Morrison discusses any possible limitations of the applicability of Eq. 4.

Morrison calculated, using the dipole model, that with the values of α and β used in this paper, the radiation and static fields are equal at 5.5 km.; using values for α and β more appropriate for his measurements he found the radiation and static fields equal at 26 km. Both values disagree with Appleton and Chapman's earlier observations (6), that the radiation field equals the electrostatic field at about 60 km.

The analysis for the linear antenna model is based on the average data available and consequently is not dependent upon troublesome problems of the channel charge distribution. The assumptions made are (1) that the distance to the field point be large compared to the channel length and (2) that the channel is vertical and continuous. The first assumption can be realized; the second is an idealization. Due to the motion of the cloud and the discrete stepped leader, the channel is most often inclined and jagged.

Both analyses of the discharge use values for α, β, and γ (Eqs. 1–3) which need revision. The value for γ permits a maximum height for

the return streamer of 2.7 km. This contradicts known data (21). Morrison (41) discusses this limitation on γ and also the current situation for α and β. His values for these parameters were published after the calculations herein were completed. The approximate current waveform for the return streamer obscures the fine structure (30) in both analyses. Using the dipole model, two other calculations of the power spectra of the nearby flash were made with the additional assumptions[5] (1) uniform channel charge distribution, and (2) constant velocity of the return stroke. The variations in the power spectra given in Fig. 2 and the above additional calculations are less significant than variations among individual strokes.

Budden (10, 14) has calculated theoretical attenuation curves for the propagation medium assuming a wave guide propagation between a lower ionospheric surface and the earth. The ionospheric surface (height: 50 km.) is considered finitely conducting, the earth, perfectly conducting. Accordingly, with the derived attenuation coefficients, he has transformed a lightning flash, assumed to have resulted from the instantaneous destruction of a cloud's electric moment, to obtain the propagated waveform at a great distance. The resultant tweek is quite similar to experimentally observed waveforms of which Fig. 3 is typical. Budden has indicated also the equivalence of the ray (ionospheric reflection) and waveguide methods of treatment of the propagation. In a more recent paper, Budden (43) applies his analysis to the 16-kc. propagation data of Weekes (41) and shows that the propagation for distances of 340 km. and 3640 km. can be explained with the use of four attenuated modes.

Thus, the daytime waveform of a distant atmospheric, characterized by decreasing instantaneous frequency and amplitude may arise from: (1) distortions of the original wave at reflection, because of the frequency dependence of the Fresnel reflection coefficient at the ionosphere (ray theory); or from (2) waveguide propagation of only a very few modes (waveguide theory). Similarly the night-time waveform of a distant atmospheric, characterized by successive discrete pips, may be considered to be: (1) the result of successive relatively distortionless reflections from the ionosphere (ray theory); or (2) the resultant of a large number of modes (waveguide theory). In contrast, Kessler and Goyder have suggested that the characteristic daytime tweek results from the mechanism of the discharge phenomena rather than from any propagation effects which they were able to observe (12). Prior to such considerations, Schonland and others have shown that the lightning discharge is not in itself oscillatory (3) (see also Norinder (44)). Still another point of view is held by Meinhold (45) who claims that atmospheric waveforms at distances of several hundred kilometers can

[5] These results are not included because of their inconsistency with the data on lightning discharge.

be explained on the basis of groundwave propagation only. The resolution of questions concerning propagation is beyond the scope of this paper. The consistency of Bowe's data, the small published uncertainties for his four fixed frequencies, and its general agreement, along with Weekes' data, with Budden's theory strongly commend the Bowe data for very low frequency propagation.

In spite of the many problems inherent in the separate studies of the discharge and the propagation of very low frequencies the results are in reasonable agreement with the known results of others (**6, 46**).

Acknowledgment

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REFERENCES

(1) HARALD NORINDER, "Cathode Ray Oscillograph Investigations on Atmospherics," *Proc. I. R. E.*, Vol. 24, pp. 287–304 (1936).
(2) R. A. WATSON-WATT, J. F. HERD AND F. E. LUTKIN, "On the Nature of Atmospherics," *Proc. Roy. Soc.*, Vol. 162, pp. 267–291 (1937).
(3) B. F. J. SCHONLAND, J. S. ELDER, D. B. HODGES, W. E. PHILLIPS AND J. W. VAN WYLE, "The Waveform of Atmospherics at Night," *Proc. Roy. Soc.*, Vol. 176, pp. 180–202 (1940).
(4) T. H. LABY, J. J. MCNEILL, F. G. NICHOLLS AND A. F. B. NICHSON, "Waveform, Energy, and Reflection by the Ionosphere of Atmospherics," *Proc. Roy. Soc.*, Vol. 174, pp. 145–163 (1940).
(5) C. E. R. BRUCE AND R. H. GOLDE, "The Lightning Discharge," *Jour. Inst. Elec. Engrs.*, Part II, Vol. 88, p. 492 (1941).
(6) H. A. THOMAS AND R. A. BURGESS, "Survey of Existing Information and Data on Radio Noise over the Frequency Range 1–30 Mc/s," Dept. of Science and Industry Research. Special Report No. 15. London, His Majesty's Stationery Office (1947).
(7) C. E. R. BRUCE AND R. H. GOLDE, "Lightning," *Research*, Vol. 2, p. 12 (1949).
(8) S. R. KHASTGIR AND ASIT SEN, "Variation of Intensity of Distant Atmospherics with Frequency Channels," *Indian J. Physics*, Vol. 23, pp. 483–494 (1949).
(9) F. F. GARDNER, "The Use of Atmospherics to Study the Propagation of Very Long Radio Waves," *Phil. Mag.*, Vol. 41, pp. 1259–1269 (1950).
(10) K. G. BUDDEN, "The Propagation of a Radio-Atmospheric," *Phil. Mag.*, Vol. 42, pp. 1–19 (1951).
(11) W. F. ZETROUER II AND W. J. KESSLER, "A Note on the Similarity of Certain Atmospheric Waveforms," JOUR. FRANKLIN INST., Vol. 252, pp. 137–141 (1951).
(12) W. J. KESSLER AND C. W. GOYDER, "Distance Determination to Thunderstorm Areas through Waveform Analysis of Associated Atmospherics," Engineering and Industrial Experiment Station, Univ. of Fla., Gainesville, Florida.
(13) P. W. A. BOWE, "The Waveforms of Atmospherics and the Propagation of Very Low Frequency Radio Waves," *Phil. Mag.*, Vol. 42, pp. 121–138 (1951).
(14) K. G. BUDDEN, "The Propagation of Radio Atmospherics, II," *Phil. Mag.*, Vol. 43, pp. 1179–1200 (1952).
(15) G. F. CATON AND E. T. PIERCE, "The Waveforms of Atmospherics," *Phil. Mag.*, Vol. 43, p. 393 (1952).

(16) P. W. A. BOWE, "A Study of Individual Radio Atmospherics Received Simultaneously at Two Places," *Phil. Mag.*, Vol. 44, p. 833 (1953).
(17) L. B. LOEB, "The Mechanism of Lightning Discharge," JOUR. FRANKLIN INST., Vol. 246, pp. 123–147 (1948).
(18) E. L. HARDEN AND J. M. CLAYTON, "Lightning Phenomena," *Westinghouse Engineer*, Vol. 11, p. 106 (1951).
(19) B. F. J. SCHONLAND, "The Pilot Streamer in Lightning and the Long Spark," *Proc. Roy. Soc. A*, Vol. 220, p. 25 (1953).
(20) T. E. ALLIBONE, "Lightning and Spark Phenomena," *Nature*, Vol. 163, pp. 708–710 (1949).
(21) D. J. MALAN AND B. F. J. SCHONLAND, "The Electrical Processes in the Intervals Between the Strokes of a Lightning Discharge," *Proc. Roy. Soc. A*, Vol. 206, p. 145 (1951).
(22) L. B. LOEB AND J. M. MEEK, "The Mechanism of the Electric Spark," Stanford (Calif.), Stanford University Press, 1941.
(23) L. B. LOEB, "Fundamental Processes of Electrical Discharges in Gases," New York, John Wiley & Sons, Inc., 1939.
(24) J. H. HAGENGUTH, A. F. ROHLFS AND W. J. DEGNAN, "Sixty Cycle and Impulse Spark-Over of Large Gaps," *Elect. Eng.*, Vol. 71, p. 318 (1952); also, A. I. E. E. *Trans.*, Vol. 71, p. 455 (1952).
(25) A. A. AKOPYAN AND V. P. LARIONOV, "Experimental Investigation of the Impulse Discharge in a Long Gap," *Electrichestvo*, No. 3, p. 31–33 (1952).
(26) HARALD NORINDER AND O. SALKA, "Mechanism of Positive Spark Discharge with Long Gaps in Air at Atmospheric Pressure," *Ark. Fys.*, Vol. 3, p. 347 (1951).
(27) R. H. GOLDE, "Lightning Currents and Potentials on Overhead Transmission Lines," *J. Inst. Elec. Engrs.*, II, Vol. 93, p. 559 (1946).
(28) J. H. HAGENGUTH, "Discussion on 'Lightning Currents and Potentials on Overhead Transmission Lines,'" *J. Inst. Elec. Engrs.*, II, Vol. 96, p. 93 (1949).
(29) A. M. CRAVATH AND L. B. LOEB, "The Mechanism of the High Velocity of Propagation of Lightning Discharges," *Physics*, Vol. 6, p. 125 (1935).
(30) D. J. MALAN AND H. COLLENS, "Fine Structure of the Main Stroke," *Proc. Roy. Soc. A*, Vol. 162, p. 175 (1937).
(31) B. F. J. SCHONLAND, "The Diameter of the Lightning Channel," *Phil. Mag.*, Vol. 23, pp. 503–508 (1937).
(32) L. TONKS, "Theory of Magnetic Effects in the Plasma of an Arc," *Phys. Rev.*, Vol. 56, p. 360 (1939).
(33) L. B. SNODDY, J. R. DIETRICH AND J. W. BEAMS, "Propagation Potential in Long Discharge Tubes," *Phys. Rev.*, Vol. 52, p. 739 (1937).
(34) D. GABOR, "Plasma Oscillations," *Brit. J. Appl. Phys.*, Vol. 2, p. 209 (1951).
(35) D. BOHM AND E. P. GROSS, "Effects of Plasma Boundaries in Plasma Oscillations," *Phys. Rev.*, Vol. 79, p. 992 (1950).
D. BOHM AND D. PINES, "A Collective Description of Electron Interactions," *Phys. Rev.*, Vol. 82, p. 625 (1951).
(36) L. H. FISHER AND B. BEDERSON, "Formative Time Lags of Spark Breakdown in Air in Uniform Fields at Low Overvoltages," *Phys. Rev.*, Vol. 81, pp. 109–114 (1951).
(37) V. FRITSCH, "Geological Investigation for the Determination of Lightning Risks," *Geofis. pura appl.*, Vol. 22, pp. 237–50 (1952).
(38) M. M. NEWMAN, Private Communication, Lightning and Transients Research Institute, Minneapolis 2, Minn.
(39) HARALD NORINDER, "Rapid Variations in the Magnetic Field Produced by Lightning Discharges," *Proc. Phys. Soc. London*, Vol. 49, pp. 364–375 (1937).
(40) J. A. STRATTON, "Electromagnetic Theory," New York, McGraw Hill. Book Co., Inc., 1948, pp. 438 ff.
(41) K. WEEKES, "The Ground Interference Pattern of Very-Low Frequency Waves," *J. Inst. Elect. Engrs.*, III, Vol. 97, p. 100 (1950).

(42) R. B. MORRISON, "On the Variation with Distance in the Range 0–100 km. of Atmospheric Wave Forms," *Phil. Mag.*, Vol. 44, p. 980 (1953).

(43) K. G. BUDDEN, "The Propagation of Very Low Frequency Radio Waves to Great Distances," *Phil. Mag.*, Vol. 44, p. 504 (1953).

(44) HARALD NORINDER AND OLAF KARSTEN, "Investigations of Resistance and Power in Experimental Lightning Discharges," JOUR. FRANKLIN INST., Vol. 253, pp. 225–233 (1952).

(45) H. MEINHOLD, "The Waveforms of Atmospherics," *Geofis. pura appl.*, Vol. 19, pp. 173–175 (1951).

(46) R. L. SMITH-ROSE, Private Communication, Radio Research Station, Ditton Park, Slough, Bucks, England.

Pulse-Type Amplifiers.—By making electrical current "beat" like your heart, only faster, General Electric engineers have found a way to amplify signals so feeble that, by use of a thermocouple, temperature can be regulated with a sensitivity of less than a hundredth of one degree. The new principle of using pulse current to amplify small signals was discovered in the company's General Engineering Laboratory.

Experimental development work has shown that a pulse-type magnetic amplifier can control equipment from a signal level of 10^{-16} watt over an ambient temperature range of $-70°$ to $+140°$ C. This compares with 10^{-8} watt attainable with conventional magnetic amplifiers.

G.E. is now developing pulse-type amplifiers for use in conjunction with conventional magnetic amplifiers wherever extreme sensitivity is desired.

The pulse principle opens the door to improved accuracy of existing control devices and development of new control devices.

Present strain gages and other devices used to measure force, movement, light and temperature have been limited in sensitivity by the ability of amplifiers to pick up their weak signals.

A cancer research organization, for example, once asked G.E. to devise a means of measuring the blood pressure in the tail of a rat. The special device constructed to detect the blood pressure produced so weak a signal that then-existing amplifiers would not respond to it.

Principal component of the pulse-type amplifier is a tiny reactor, barely two-thirds the size of a shirt button. It consists of two windings of copper wire around a circular core made of saturable magnetic material.

The reactors are used in cascade, each one boosting the signal to a higher level. Pulse current enters one of the copper windings, while the signal, converted by conventional means to electrical energy, enters the other winding. Amplification results from the action of the signal on the magnetic state of the core. The pulse current is then controlled by the core to produce an output signal. Direct interstage coupling is possible and no rectifier or non-linear ohmic devices are required between stages.

Hydraulic-Lift Hand Truck.—Precision Equipment Co. (Chicago) announces production of the "Shop Caddy," a rugged two-wheel hand truck which embodies a hydraulic lift capable of raising loads of as much as a quarter ton. The Shop Caddy is the ideal tool for loading and unloading trucks, for stacking kegs and boxes, for moving dies and for moving heavy units in assembly line production. Its lifting platform, in the down position, is at floor level for easy loading. When loaded, a few strokes of the lever will raise the load to the proper height. A four-speed pump ram is furnished as standard equipment so that the lifting speed may be set according to the load.

The Shop Caddy is an amazingly useful tool for hundreds of material handling jobs. Factories, warehouse and distributing firms, institutions and retailers, will find continual multiple uses for this convenient, safe method of lifting and moving heavy loads. The handy Shop Caddy has a lift capacity of 500 lb. and a lifting height of 36 in. It's platform is 16 in. long and 20 in. wide. The over-all height is 50 in. and over-all width is 23 in. The roller bearing wheels are of 8-in. Moldon Rubber.

ACCELERATION TO COSMIC RAY ENERGIES BY ELECTROMAGNETIC INDUCTIVE ACTION *

BY

W. F. G. SWANN [1]

In 1933[2] I suggested a mechanism according to which charged particles could acquire cosmic ray energies by electromagnetic inductive action in the stars. The mechanism invoked the changing magnetic fields known to exist over large areas in the stars, and exemplified in their most obvious form in the magnetic fields associated with sunspots. The mechanism may also be applied to galactic magnetic fields.

While, in my original paper, I used sunspots as an illustration, it was never my intention to imply that all cosmic rays came from the sun, nor indeed to imply that even the rays from the sun itself necessarily originated in the spots. The principal reason for invoking sunspots at all lay in the fact that, as has since been emphasized many times, there are grave difficulties in understanding how magnetic fields can change with time to any significant degree in large masses of highly conducting material, and in assuming a figure for the rate of change of magnetic field in my calculations, it was important to avoid using a value greater than 2×10^{-3} gauss per second, which rate of change is *known* to occur in sunspots and so is a permissible value for cosmological calculations of this kind.

Criticisms of the betatron mechanism have been made for the most part on two bases.

THE CRITICISM MADE BY ALFVÉN [3]

First, we have the criticism of H. Alfvén, who writes:[4]

> A serious objection against this model is that the conductivity of the corona outside a sunspot is so high that the generator is short-circuited.

* Assisted in part by the Joint Program of the Office of Naval Research and the United States Atomic Energy Commission. The contents of this paper, together with many other considerations, were presented by the writer as part of the Cosmic Ray Symposium held at Durham, N. C., November 30 to December 2, 1953, under the auspices of the National Science Foundation.

[1] Director, Bartol Research Foundation of The Franklin Institute, Swarthmore, Pa.; a Senior Advisor for The Franklin Institute Laboratories for Research and Development, Philadelphia, Pa.

[2] W. F. G. SWANN, *Phys. Rev.*, Vol. 43, p. 217 (1933); JOUR. FRANKLIN INST., Vol. 215, p. 273 (1933).

[3] From conversations with Dr. Alfvén, I understand that he no longer maintains the objections here cited, so that my only reason in recalling them at this time lies in the fact that many other physicists may have become conscious of the objections, so that it is well that they should be resolved.

[4] H. ALFVÉN, *Phys. Rev.*, Vol. 75, p. 1732 (1949).

In other words, the electric field must accelerate all particles in the region in question, but the available energy does not suffice to give them cosmic-ray energies. It should also be observed that this model is not reconcilable with a solar origin of the whole cosmic radiation, because fields much stronger and more extensive than sunspot fields must be assumed in order to account for the highest cosmic-ray energies.

Now as regards the first part of this criticism, it is to be observed that the changing magnetic fields are *known to exist*, and rates of change of the order 2×10^{-3} gauss per second used in my calculations are found in nature. It is true that there may be difficulty in understanding how this may come about, and an attempt to find the cause raises interesting speculations,[5] but with its existence guaranteed from experiment, the operation of the acceleration mechanism is guaranteed.

As regards the last sentence in Alfvén's criticism implying the necessity of invoking very high magnetic fields for the highest cosmic ray energies, it must be remarked that it is not large magnetic field which is important in the problem under discussion, but large value of the product of orbital radius with the value of the magnetic field at the time when the energy acquired is considered. In the problem cited, a cosmic ray energy of 2×10^{10} e.v. was calculated as attained in one second for a changing magnetic field which, at the time of realization of this energy, had attained a magnitude of only 2×10^{-3} gauss. If the particle continued to describe the orbit, as indeed would be permitted by the calculation, it would attain an energy of 2×10^{16} e.v. by the time the magnetic field had grown to 2000 gauss.

CRITICISM HAVING TO DO WITH THE MECHANISM ITSELF

E. Teller[6] has questioned the fact that particles can really acquire energy by the mechanism in question. It must be pointed out, however, that in my original paper the matter was not left at a stage in which the mere existence of *electromotive forces* was pointed out, leaving the questions of possible particle motions to take care of themselves. The paper carries a particular problem right through, establishes the orbit, and calculates the rate of acquisition of energy. This point seems to have been missed by some readers, possibly because I started out with a general dynamical treatment in terms of the Hamiltonian equations, a treatment capable in principle of handling orbits of any degree of generality, and only then, as an illustration, worked out in detail the particular case referred to. For this reason, in what follows, I give a special treatment of this particular problem, using the most elementary principles, so that the exact mechanism by which the orbit

[5] Such speculations, referred to briefly in the Symposium already cited, will be discussed in another communication.

[6] E. TELLER, *Proc. of the Echo Lake Symposium*, June 23–29, 1949, pp. 146 and 147.

is maintained can be visualized. The results are, of course, in agreement with the earlier treatment.

Following the presentation of the problem, as aforesaid, we shall return to Teller's criticism and endeavor to show the precise reason why it is inacceptable.

ELEMENTARY CONSIDERATIONS OF THE SPECIAL PROBLEM OF A CHARGED PARTICLE ACCELERATED BY INDUCTION IN A CHANGING MAGNETIC FIELD

Let the magnetic field be along the axis of z and increase with time. Let it be axially symmetrical about this axis. Let N_r be the magnetic flux within this radius.

The field E_θ is entirely tangential, and is given by

$$2\pi r E_\theta = -\frac{1}{c}\frac{dN_r}{dt}. \tag{1}$$

If v is the velocity of the particle at any instant, and T is the kinetic energy

$$\frac{dT}{dt} = \left|E_\theta v e\right| = \frac{ve}{2\pi r c}\frac{dN_r}{dt}, \tag{2}$$

provided that the particle moves in the circle of radius r. In order that the particle shall move in the circle of radius r, it is necessary to have

$$\frac{mv^2}{r} = \frac{H_r e v}{c},$$

or

$$\frac{mv}{r} = \frac{H_r e}{c}, \tag{3}$$

where m is the relativistic mass.

Now, since T involves only v and m_0, Eq. 2 is really an equation for v as a function of time, if N_r is specified. Equation 3 is an additional equation which must be satisfied if the particle is to move in the circle of radius r. The condition that (2) and (3) shall both be satisfied will be found to place a restriction on N_r as a function of r, this restriction defining the particular problem we are considering, which is one where the increase of H_r with time just fits with the increase of T with time in such a manner as to cause (3) to hold continually and thus keep the particle moving in the circle of radius r. The additional well-known relation between T and mv will be needed. It is

$$m^2v^2c^2 = T^2 + 2m_0c^2T. \tag{4}$$

Our plan is then to satisfy Eqs. 2, 3 and 4.

From (2) and (3) we can eliminate v explicitly and obtain

$$mc^2 \frac{dT}{dt} = \frac{e^2 H_r}{2\pi} \cdot \frac{dN_r}{dt}$$

$$(T + m_0c^2) \frac{dT}{dt} = \frac{e^2 H_r}{2\pi} \cdot \frac{dN_r}{dt}$$

$$\frac{dT^2}{dt} + 2m_0c^2 \frac{dT}{dt} = \frac{e^2}{\pi} H_r \frac{dN_r}{dt}. \tag{5}$$

Now (3) and (4) require

$$H_r^2 e^2 r^2 = T^2 + 2m_0c^2 T, \tag{6}$$

that is,

$$2e^2 r^2 H_r \frac{dH_r}{dt} = \frac{dT^2}{dt} + 2m_0c^2 \frac{dT}{dt}. \tag{7}$$

Hence, from (5) and (7)

$$e^2 r^2 H_r \frac{dH_r}{dt} = \frac{e^2 H_r}{2\pi} \frac{dN_r}{dt}$$

$$\frac{1}{2\pi} \frac{dN_r}{dt} = r^2 \frac{dH_r}{dt}. \tag{8}$$

If H_ρ is the value of H for any radial distance ρ which is less than r, then

$$N_r = 2\pi \int_0^r H_\rho \rho d\rho$$

and (8) demands that

$$\frac{d}{dt} \int_0^r H_\rho \rho d\rho = r^2 \frac{dH_r}{dt} = \frac{d}{dt} (H_r r^2). \tag{9}$$

We can satisfy this condition if, at each instant of time, $H_\rho \rho$ is independent of ρ and so is equal to $H_r r$. In this case (9) becomes

$$\frac{d}{dt} (H_r r^2) = \frac{d}{dt} (H_r r^2)$$

which is true.

The condition $H_\rho \rho = H_r r$ for all values of t implies, of course, that $H_\rho / H_r (= \rho / r)$ is independent of time. In other words, it implies that the percentage time rate of change of field is the same at all points.[7]

[7] The infinity for H_ρ when $\rho = 0$ is trivial, since a considerable variation in the form of H_ρ near $\rho = 0$ would have but little effect upon N_r. Thus, if $H = A/\rho$, the flux through a circle of radius a is $\int_0^a 2\pi A \rho d\rho / \rho = 2\pi A a$, and tends to zero when a tends to zero. If we have $H = A/\rho$ for $\rho > a$, where a has any value whatever, and if we have H independent of ρ for $\rho < a$, and

The energy T attained by the time the field has attained the value H_r, starting from zero, is now most easily calculated from (6) which may be written

$$T\left(1+\frac{2m_0c^2}{T}\right)^{\frac{1}{2}} = H_r e r$$

and, to a first approximation,

$$T + m_0c^2 = H_r e r$$

or, in electron volts,

$$T + m_0c^2 = 300\, r H_r n \text{ electron volts}, \tag{10}$$

where $e = n\epsilon$ and ϵ is the electronic charge.

It will be seen that if T is large, it is not very sensitive to the rest mass m_0, but is approximately proportional to n.

If $r = 3 \times 10^{10}$, and $H_r = 2 \times 10^{-3}$ gauss, and if $m_0c^2 = 10^9$ for a proton, we have, for such a particle,

$$T = 1.8 - 0.1 = 1.7 \times 10^{10} \text{ e.v.}$$

For an alpha particle, we should have

$$T = 3.6 - 0.4 = 3.2 \times 10^{10} \text{ e.v.}$$

If the field on the orbit of the particle changes uniformly from zero at a constant rate equal to 2×10^{-3} gauss per second, which corresponds to the rate of change in the vicinity of a sunspot, the above energies will be attained in one second.

The electric field E_θ is given by (1), which, in view of (8), is equivalent to

$$E_\theta = \frac{r}{c}\frac{dH_r}{dt}.$$

For the value $dH_r/dt = 2 \times 10^{-3}$ cited above,

$$E_\theta = 2 \times 10^{-3}\frac{r}{c} \times 300 = 0.6r/c \text{ volt/cm.}$$

For $r = 3 \times 10^{10}$

$$E_\theta = 0.6 \text{ volt/cm.} = 2 \times 10^{-3} \text{ e.s.u.}$$

This value of E_θ is equal to H_r at the time when the above calculated energies are attained at the end of a second.

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such that $\pi a^2 H = 2\pi A a$, which condition can be provided by a cylindrical current sheet, then the flux through any circle of radius $r(>a)$, and the value of H_r will be the same as if the law $H = A/\rho$ held down to $\rho = 0$.

Thus, in the above calculations, the *electric field is less than the magnetic field for the whole period of our calculation.* Of course, after the lapse of one second in the above case, H_r becomes greater than E_θ, but the energy continues to increase with time. This point is of significance in relation to matters to be discussed later in relation to Teller's criticisms.

The above calculation has been made for the special case where H_r is inversely proportional to r and, for this law, a particle can be continuously accelerated at *any* radius r. If we have some other law, there will, in general be no radius, or at most a finite number of radii at which the circular orbit is realized.

Thus (8) is satisfied if, at all values of r,

$$N_r = 2\pi r^2 H_r.$$

If ρ applies to a radial distance less than r, we must therefore have

$$2\pi \int_0^r H_\rho \rho d\rho = 2\pi r^2 H_r. \tag{11}$$

Suppose

$$H_\rho \rho = \frac{df(\rho)}{d\rho} \tag{12}$$

where $f(\rho)$ is some arbitrary function of ρ. Then (11) demands that

$$f(r) - f(0) = r^2 H_r. \tag{13}$$

In general this provides an equation for r. Thus suppose

$$f(\rho) = A\rho^3 - B\rho^2.$$

Then, using (12), Eq. 13 becomes

$$Ar^3 - Br^2 = \frac{r^2}{r}(3Ar^2 - 2Br)$$

$$2Ar^3 - Br^2 = 0$$

which has a finite solution for r at $r = B/2A$.

If

$$f(\rho) = c\rho$$

Eq. 13 is satisfied if

$$cr = \frac{r^2}{r} c.$$

This gives a solution for *all* values of r, and represents the case rH_r = constant already studied.

CONCERNING E. TELLER'S CRITICISM

Teller[6] refers to the matter of crossed electric and magnetic fields, and states as follows:

> The particle is in a magnetic field. But the electric field in which it finds itself is due to the change of the magnetic field. Therefore, there is a magnetic field, and an electric field produced with the magnetic field; and the one which is the smaller in the ratio of v/c is the electric field. A particle in such crossed fields will move in cycloids. These cycloids will have precisely the property that they will appear to be just a simple circular motion in a certain moving coordinate system. In the same system all particles—electrons, protons, etc.—will move on circles. Therefore, there are no accelerations of particles, but, by the very magnetic field that causes the electric field, the particles will be taught to follow around the sun and effectively will not be accelerated.

In another place, Teller states as follows:

> I would like to emphasize again the point that changing magnetic fields, either due to a change in the magnetic moment or to motion of the particle, will have an effect which will cancel in a first approximation, because of the kind of transformation used. However, it will then leave residual effects for individual particles. This acceleration may be actually an acceleration or a deceleration. If this is repeated several times there will remain, on the average, an energy-gain per collision which is v^2/c^2 times the original energy of the particle, where v is the velocity of the medium which carries the magnetic field.

It is the second of these quotations which is more directly applicable to the problem which is the subject of the present paper.

Now, in the first place, it is to be observed that only when the electric field is less than the magnetic field can we transform away the former, the velocity of transformation along the x axis being given, in fact, by

$$0 = E'_y = \beta\left(E_y - \frac{v}{c}H_z\right)$$

so that

$$v/c = E_y/H_z,$$

where, in our case, the instantaneous axis of x is taken radially, while E_y is tangential, dashed letters corresponding to the transformed system S', and undashed letters corresponding to the untransformed system S.[8] In the problem considered in this paper, the electric field remains *greater* than the magnetic field for the whole period during which the proton is being accelerated from zero energy to 1.7×10^{10} e.v. Thus, in no sense does Teller's criticism apply to this phase of the problem.

[8] When E is greater than H we can, in fact, transform away the magnetic field, leaving only an electric field (see W. F. G. SWANN, "Cosmic Rays," JOUR. FRANKLIN INST., Vol. 251, p. 120 (1951).

However, in our particular problem, the criticism does not apply even when the magnetic field has grown to a value greater than the electric field, as the detailed working out of the problem shows, since the analysis places no restriction to the effect that E must be greater than H for continual increase of energy to become realized in this problem.

The failure of Teller's criticism in this case, even when $H > E$, follows from the following considerations: It is true that when $E < H$ in the case of crossed magnetic fields which are constant throughout space, we can perform a relativity transformation to a system S' in which the transformed field is a pure magnetic field and in which a charged particle moves in a circle with no change of energy. However, in order that this conclusion shall hold even approximately in the approximate case where E and H are not constant in magnitude and direction throughout space, it is necessary that they shall be *sensibly constant over the region covered by the orbit* (a circle in S' and a cycloid in S). In such a case, and in an axially symmetrical problem, the particle, as viewed in S, would gain energy when it was moving in one direction tangentially to the radius vector from the origin, and it would lose energy when moving tangentially in the other direction. When moving radially, it would neither gain nor lose energy, and it would neither gain nor lose energy in a complete cycle. However, in our problem the situation is vastly different. The orbit of the particle in S is a circle with radius r, which is the distance from the origin of coordinates to the particle. It is about a million kilometers in circumference, and as we travel around this circumference, the field E changes in direction continuously through a range of 2π. As a matter of fact, at each instant the particle is in the condition in which it moves perpendicular to the instantaneous x axis drawn for the purpose of the relativity transformation, and in this condition its rate of increase of energy is of the same sign continually and equal to the product of the absolute value of E and the absolute value of the velocity.

There is another aspect of the foregoing matter which is of interest. In my original paper[2] I showed that whatever the motion in the axially symmetrical field, the particle will always gain energy if $|E| > |\dot{r}H/c|$, where $\dot{r}$ is the radial velocity. In the particular problem considered when the orbit is circular, $\dot{r}$ is zero, so that, regardless of the value of H, we always have $|E| > |\dot{r}H/c|$, so that this condition is always satisfied.

DISCUSSION OF "THE MEANING OF THE VECTOR LAPLACIAN"

BY

HAROLD K. FARR [1]

ABSTRACT

A proposal has been made recently that a special notation be adopted for the Laplacian of a vector. It is shown that such a notation is unjustified since the usual scalar Laplacian gives the correct result when operating on a vector.

In a recent article Moon and Spencer (1)[2] develop expressions for the Laplacian of a vector in rectangular, cylindrical and spherical coordinate systems. It is indeed surprising that these expressions are not listed in most standard texts on field theory. In making them easily available, these authors have satisfied an important need.

They point out correctly that some confusion may arise from the fact that the expression for a scalar component of the Laplacian of a vector does not in general have the same form as the Laplacian of a scalar. They propose to avoid the confusion by using two different symbols for the Laplacian, depending on whether operation is on a scalar or a vector.

This dual notation is unjustified and would very likely only add to the confusion. Such a notation implies that the usual scalar expression for the Laplacian is not necessarily correct when operating on a vector. This belief seems to be rather widespread (2, 3). Now, vector operations are properly defined to be independent of the choice of coordinate system and this is in fact true of the Laplacian. The confusion apparently results from overlooking an important point in the computation of the derivative of a vector. It must be remembered that the unit vectors $\bar{a}_r$, $\bar{a}_\theta$, $\bar{a}_\phi$ used in cylindrical or spherical coordinates are functions of position. For example, whereas in rectangular coordinates

$$\frac{\partial}{\partial y}(\bar{a}_x E_x) = \bar{a}_x \frac{\partial E_x}{\partial y},$$

in cylindrical coordinates

$$\frac{\partial}{\partial \theta}(\bar{a}_r E_r) = \bar{a}_r \frac{\partial E_r}{\partial \theta} + \bar{a}_\theta E_r.$$

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[1] Specialist, Insulation Research, High Voltage Laboratory, General Electric Company, Pittsfield, Mass.

[2] The boldface numbers in parentheses refer to the references appended to this section of the discussion.

If the derivatives of the unit vectors are computed correctly the scalar Laplacian may be used to operate on a vector in any coordinate system. Thus, if one makes use of ∇^2 expressed in cylindrical coordinates in scalar form as given by Eq. 2 of Moon and Spencer to operate on $\bar{E}$ expressed in cylindrical coordinates one gets exactly Eq. 9*b* of their paper. Likewise their Eq. 10*c* may be used to obtain their Eq. 9*c*. It might be remarked that it would be just as logical to suggest using different notations for, say $\partial/\partial\theta$ when operating on vectors and scalars as for ∇^2. In either case a scalar component resulting from operation on a vector may be different from the result of operation on a scalar and for exactly the same reason. There appears, therefore, to be no reason for abandoning the well accepted notation for the Laplacian.

Expressions for the derivatives of the unit vectors are given in standard texts (4). They are reproduced below as required for computing the Laplacian of a vector in cylindrical and spherical coordinates from the conventional scalar form of the operator in those systems.

For cylindrical coordinates

$$\frac{\partial \bar{a}_r}{\partial \theta} = \bar{a}_\theta, \qquad \frac{\partial \bar{a}_\theta}{\partial \theta} = -\bar{a}_r$$

and all other derivatives are zero.

For spherical coordinates

$$\frac{\partial \bar{a}_r}{\partial r} = 0, \quad \frac{\partial \bar{a}_r}{\partial \theta} = \bar{a}_\theta, \quad \frac{\partial \bar{a}_r}{\partial \psi} = \bar{a}_\psi \sin\theta$$

$$\frac{\partial \bar{a}_\theta}{\partial r} = 0, \quad \frac{\partial \bar{a}_\theta}{\partial \theta} = -\bar{a}_r, \quad \frac{\partial \bar{a}_\theta}{\partial \psi} = \bar{a}_\psi \cos\theta$$

$$\frac{\partial \bar{a}_\psi}{\partial r} = 0, \quad \frac{\partial \bar{a}_\psi}{\partial \theta} = 0, \quad \frac{\partial \bar{a}_\psi}{\partial \psi} = -\bar{a}_r \sin\theta - \bar{a}_\theta \cos\theta.$$

It should be pointed out that the last term on page 555 of the subject article should be

$$\frac{\cot\theta}{r^2}\frac{\partial E_\theta}{\partial \theta} \text{ rather than } \frac{\cot\theta}{r^2}\frac{\partial E_\theta}{\partial r}.$$

REFERENCES

(1) PARRY MOON AND DOMINA EBERLE SPENCER, JOUR. FRANKLIN INST., Vol. 256, p. 551 (1953).

(2) ERNST WEBER, "Electromagnetic Fields," Vol. I, New York, John Wiley & Sons, Inc., 1950, pp. 541, 542.

(3) ARNOLD SOMMERFELD, "Lectures in Theoretical Physics," Vol. III, "Electrodynamics," New York, Academic Press Inc., 1952, p. 32.

(4) LEIGH PAGE, "Introduction to Theoretical Physics," Third edition, New York, D. Van Nostrand, 1952, p. 65.

AUTHORS' REPLY

Apparently Mr. Farr agrees with us in all points of fact and differs in only one question—and that a matter of opinion. The method advocated by Mr. Farr was not "overlooked" in our paper: it was ignored because it is rather remote from the modern tensor approach. No question of "correctness" or "incorrectness" is involved. The rules of differentiation of unit vectors are well known; and if rightly applied, they lead to the equations given in our paper.

Note, however, that we have given the equation for the vector Laplacian *in any orthogonal coordinate system.* Derivatives of unit vectors are easily obtained in spherical and circular-cylinder coordinates, where the geometry is readily visualized; but even Mr. Farr might find the method troublesome in the more esoteric coordinate systems.

Mr. Farr states that "vector operations are properly defined to be independent of the choice of coordinate system." Yet books on vector analysis often violate this admirable criterion by stating general definitions in terms of rectangular coordinates. Instead of using such a specialized definition of divergence, we should preferably write

$$\text{div } \mathbf{E} = \lim_{\Delta v \to 0} \frac{\int \mathbf{E} \cdot d\mathbf{S}}{\Delta v}.$$

Similarly,

$$\text{curl}_i \, \mathbf{E} = \lim_{\Delta S \to 0} \frac{\oint_i \mathbf{E} \cdot d\mathbf{s}}{\Delta S}.$$

Now what about the Laplacian? Mr. Farr ignores his criterion by apparently defining the operator in rectangular coordinates:

$$\nabla^2 = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}.$$

From the tensor viewpoint, this is not an adequate definition. Instead, we may write for a scalar,

$$\nabla^2 \varphi = \text{div grad } \varphi.$$

But this definition cannot be extended to a vector by replacing φ by $\mathbf{E}$, because grad $\mathbf{E}$ *is not a tensor quantity.* To follow Farr's excellent criterion, we must define the vector Laplacian by an entirely different equation (Eq. 4 of our paper).

Of course, it is still possible to represent the two concepts by the same symbol. Indeed, one might also represent curl and divergence by ∇^2. Very precise thinking would still allow one to get the correct

answer to an involved bit of vectorial manipulation—but only at the expense of unnecessary mental work.

An ideal notation reduces mental labor to a minimum, so that routine manipulation can be relegated essentially to the autonomic nervous system, leaving the higher centers free to deal with problems which they alone can handle. We believe that the use of separate symbols for scalar and vector Laplacians is a step toward the ideal.

PRESENTATION OF THE FRANK P. BROWN MEDAL *

This Medal (founded in 1938) is awarded to inventors for discoveries and inventions involving meritorious improvements in the building and allied industries.

(To Frank Lloyd Wright, Architect, Spring Green, Wisconsin.)

MR. ROLPH: Ladies and gentlemen, we will now hear from Mr. Coleman Sellers, a member of the Science and Arts Committee, who will tell us why the Frank P. Brown Medal should be awarded to our distinguished guest, Mr. Wright. Mr. Sellers.

MR. SELLERS: Mr. President, I present Frank Lloyd Wright for an award. Our candidate is without question the dean of American Architecture. His influence on the architectural thought of our times has been great and far-reaching, both in this country and abroad. His career is unmatched, extending over a period of sixty years and still going on. Mr. Wright has always insisted on a return to true basic architectural principles. In that sense, he is a true traditionalist. He has consistently hewed to his own line and refused to be submerged by the architectural trends of the times. Our candidate has shown remarkable foresight, imagination, and a brilliant romanticism of his own. He has always contributed the sensitivity of an artist to the architectural problems that he solved. In addition, he has always had a strong idea of what the technological advancements of our times have meant to architecture and he has used, with great discernment, the many new inventions available in the field.

The work of Mr. Wright is probably most generally known by his homes. He has designed buildings, however, of all types, including commercial, industrial and civic. All have shown great originality. For instance, the Larkin Building in Buffalo built in the nineties, a contemporary of the Flatiron Building in New York, had many advanced features for that time. In the first place, it contrasted sharply with the architecture of that period, which was tending more and more to elaboration. This office building was designed in the terms of straight lines and flat planes. The heart of the building was the many-galleried court, lighted from above and from windows on the sides that were sealed from dirt and noise of the nearby railroad yard. The furnishings and filing systems were built in of steel. This building had many firsts: the first metal furniture made in the United States, the first air-conditioned office building, the first use of magnesite as architectural material, the first metal-bound plate glass doors and windows,

* Proceedings of the presentation of the Frank P. Brown Medal, deferred from the 1953 Medal Day Ceremonies (see this JOURNAL, Vol. 256, p. 523 (1953)), and presented June 4, 1954, in the Lecture Hall.

and so forth. Unity Temple, built in 1905, in Oak Park was a Unitarian Church which was quite remarkable. Both outwardly and inwardly it went entirely contrary to anything ever constructed. Mr. Wright provided a quiet, simple, well-lighted room, which gave the effect of a happy cloudless day as he predicted. This building was the first concrete monolith in the world. That is, it was the first building designed for and completed in the wooden forms into which the concrete was poured. Walls, roof and floor were all made of this comparatively new building material. One of Mr. Wright's most famous buildings is the Imperial Hotel in Tokyo. It was built to withstand earthquakes and went through the terrible quake of 1923 unscathed while practically all of Tokyo was in ruins. This was no mere chance, for the architect studied his problem most thoroughly and decided he would not fight the earthquake but make his building so that it could ride out the waves of the earth which he found were produced during quakes. Test borings showed him there were eight feet of top soil resting on sixty to seventy feet of liquid mud. By carefully making concrete test piles and loading them with pig iron, he determined how much load they would support in various locations. The entire hotel was then designed on supporting piles about eight feet long.

Mr. Wright has been the recipient of many honors and medals. Among these are the highest awards of such organizations as the American Institute of Architects and the Royal Institute of British Architects. He has had similar awards from a dozen different countries. I take great pleasure in presenting Frank Lloyd Wright, of Taliesin, Wisconsin, as a candidate for the Frank P. Brown Medal, "In consideration of his very extensive contributions to the entire field of architecture over a period of more than half a century, by means of countless and varied buildings, by reason of his many writings and lectures, and through his Fellowship at Taliesin, Wisconsin."

MR. ROLPH: Mr. Wright, on behalf of The Franklin Institute of the State of Pennsylvania, I present to you this Frank P. Brown Medal.

MR. WRIGHT: (Holding Medal up) So you can all see it.

MR. ROLPH (*cont.*): . . . and this certificate goes with the Medal and the report which also accompanies the Medal.

MR. WRIGHT: What is this for?

MR. ROLPH: We are very happy to make this award to you, sir, for the reasons which Mr. Sellers has given to us.

MR. WRIGHT: A very fine medal indeed, Mr. Rolph.

MR. ROLPH: Now we hope, Mr. Wright, that this fine unusual audience which expresses its admiration for you. . . .

MR. WRIGHT: Extraordinarily intelligent!

MR. ROLPH: . . . will have the pleasure of hearing more of your wit and wisdom, sir.

MR. WRIGHT: I don't know about the wisdom and I'm never sure of the wit.

(*See following page for full text of Mr. Wright's acceptance speech.*)

AMERICAN ARCHITECTURE *

BY

FRANK LLOYD WRIGHT [1]

Ladies and gentlemen: this is a serious occasion. I was blamed for recently accepting, with lightness, and, I thought, some grace—a similar honor from the American Institute of Arts and Letters. The comment upon the reception of the medal at that time was that mine was a cranky and cocky acceptance. I am not cranky now and I am not cocky. I am seriously gratified to have Science thus recognize one in the field of Art, which is, after all, rather low down at this time in the history of our world. So I am glad to find myself here, a mere artist, in the presence of all that America knows anything about in the way of progress (in culture or anything else) and that is to say, Science. You know very well, just as I know from a lot of experience during sixty years past that Science has given us all a magnificent toolbox full of splendid tools that we don't yet know how to use. Now, it is true that if we are ever going to learn how to use them, it isn't going to be science that is going to teach us. At least, we are beginning to wake up to that fact and I suppose that here tonight, an artist among scientists is something like a lady among lions—or is it a lion among ladies; anyway, a terrible thing; I think I should owe what I do owe of distinction on this occasion to the fact that Science is here awarding the medal to an Artist. So I accept this token of honor in that unique spirit because I believe it is—it must be—unique.

A Civilization, ladies and gentlemen, what is a Civilization? There have been so very many but where are they all now? You see—a civilization is only a way of life—that's all it is. And you'll have to forgive me for now reminding you of the fact that that's all we have—*a way of life*. A true Culture would be one where Religion and Art come in together, hand in hand—as they must. It is the way of making that way of life a *beautiful* way of life. Have we begun on it? Look about you. It isn't necessary to point out our buildings, they are growing more and more negative and desolate and inhuman. What have *we* emphasized as the *Beautiful* in our way of life? What have we in it all that we can point to with pride as an awakening of an indigenous culture of our own? Now,—as I am,—wouldn't *you* too be put to it to answer? You wouldn't say painting, would you? You see in me one of the few gray heads you'll see today that ever had the benefit of

* Acceptance speech delivered by Mr. Wright, on the occasion of the award of the Frank P. Brown Medal to him, June 4, 1954, in the Lecture Hall of The Franklin Institute.

[1] Architect, Spring Green, Wisconsin.

Froebel's wisdom when he was a youngster of six, seven etc. Now it was Froebel's idea that no child should be allowed to draw directly from nature until he had mastered the rudimentary forms and elements of the various elemental-forms in nature: the square, the triangle, the spheres, the circle, all forms that are basic to Nature—primitive. Here is the square—symbol of integrity; the triangle—symbol of aspiration; the sphere or the circle infinity—etc—all forms in one dimension, the flat dimension. Then the forms go into the third dimension. Out of the circle you get the sphere; out of the square you get the cube; out of the triangle comes the tetrahedron, etc. Well, that significance is merely a little indication of their importance in creation. We haven't time to talk much about this thing; but I've touched upon it to show how the elemental basis of thought in creative architecture goes back to these primary things, primarily. As a result when I learned these things thoroughly, I didn't care to draw from nature, or to boondoggle with the surface-effects of anything at all. I wanted to combine, construct, to build, to create with these simple elements, and I believe that's where creation must begin in education. I cannot believe that you can make an artist creative the same way that you make a scientist or a businessman. I do not think that we as a people (I won't say as a Culture, but as a way of life) understand the difference between the artist and the scientist, or Art and Science. Radically, they occupy different worlds at the present time, as always. But, some day the synthesis will be made between them; and I believe that synthesis is one thing a great institute like this should be busy with and might accomplish. Perhaps, beyond any other thing that synthesis would be *the* missing synthesis. Standing before you here tonight speaking to you in this scientists' hall from this scientists' rostrum, that is one of the hopeful signs I can be cheered by, this evidence that Science is awakening to the fact that although it can take things apart it can never put them together again without the creative artist. Now the more you think about it the more you'll see that in that missing synthesis is where our civilization is today. We worship this god Science and not with un-reason. But with un-reason we have neglected Art and Religion, those two essentials which always have and always will constitute the *soul* of a civilization. Now a scientist does not know how to draw the line between the Curious and the Beautiful. That's where your creative artist comes in and that's where our culture as a nation must come in when we really have one. Until we as a nation know how to draw that line between what is merely curious and what is truly beautiful, we haven't a culture of our own and without that discrimination you're not cultured beings yourselves. It matters little how much education you've received in the backward and forward of our times or how much you may have been *conditioned* by favorable or unfavorable conditions or by the accepted educational conditioning

of the mind; you are ignorant of that essence which is the only thing which can save a civilization as a culture for the future—if it is unknown to you. These are strong words, I suppose. You haven't heard them often. Why? You haven't heard them because all the education you know and all the educational systems established in our country today are based upon some scientific thesis of this or that and expounded by talk by men largely themselves (shall I say) mere scientists? We have largely imported the German ways of thought. The German idea of living things is essentially scientific, seldom or never deeply artistic; never can be creative in artistic sense because the German self wasn't born that way—Goethe and Beethoven excepted. Nor the English. But we Americans were born in so many different ways. All the ways there are. We are a "mongrel" civilization. Aren't we? There is no definite trend of thought which we have inherited outside the British and (God help us all) all we ever got from the British was the British dormitory town, we called it Old Colonial. No. We didn't get the beautiful old England. For instance, we didn't get the best of what England got from France—much of it. The old-colonial, of course, we did get from England. Where did England get it? From France. And where did France get it? From Italy. Music still speaks Italian. What is the Italian word *chiaras curo*—painting speaks it. You know that it was Italian. So it goes. There was the great Dante, the great liberator of what we call Literature. He too was Italian wasn't he? Well, also from Italy, from the Italians came what soul this Art we call Architecture ever has had. Now it is the greatest of tragedies 500 years old now at least—that the Italians thought art could be restated in the old Greek terms and they got what they called the Renaissance and we got this "rebirth" from them. If you go to Europe with love in your heart now, you'll see how all the great thought and feeling of the Middle Ages recorded there in stone, brick and mortar, was desecrated, yes, demoralized by that academic sense of the old pictures made by Greek Architecture made new. That, too, is when the painter first came in to curse architecture; wherefrom we got the idea that a painter could see a building. He really cannot. Much less can he do one. But then and there Michaelangelo gave us the symbol of authority (the dome in air on posts) that, in common with other nations, we have adopted, which is, of course, completely bogus from any structural point of view—or standpoint with integrity; utterly phony—an arch up in the air on columns, on posts, a very fancy picture but nonsensical construction. Yet this anachronism became the symbol of authority for the whole world. So you can see how little organic thinking and how little deep feeling has gone into this matter of building if it is to be a quality in the life inhabiting that building. We might call that quality *integrity?* Now, it is that simple *integrity* that's lacking in our lives today—integrity

and so—no *depth* of feeling. We have developed insensate voracity by way of speed to a point dangeous to the future of our civilization, such as it is. Science has aided and abetted the circumstance without conscience. By way of Science we have all the means of rapacity, speed and destruction. Where is salvation coming from? Well, we must again have recourse to those things of the Spirit which have always borne the name Art and Religion. The two are as one. They work together or we cease to work at all, as a culture. No future. As a Civilization—pretty close to the end. Now who built the first city? I myself have just learned from Rabbi Cohen today. How many of you know who was originator of what we call the modern city? Ladies and gentlemen, please speak up! Do you know? I didn't know. It was Cain, the murderer of his brother. He built the first city. He was the author of urbanism. In "Urbanism" isn't Cain still murdering his brother? Who then is going to do something about that? Science? No. Science can keep on building these great inimical blocks of non-entity, these great negations of the richness and the joy of the humane life of the American individual; these great masses of what? They are built by the insurance companies of America (bless *your* money). The people's savings are entrusted to these merciless magnates "safely" spent to be paid back in time of need. That's why I never would take out a dollar's worth of insurance. And do you know ("sotto-voce") I recommend to you the same thing. If that's the best insurance companies can do with money, then let's put an end to so-called insurance and pay for our own impotence or carelessness in our own way—every man responsible for his own mistakes and he be the profiteer of his own virtues. I'm just paying now for one of mine. Last spring I started a dried-grass fire at Taliesin with only one of my boys in sight. We hadn't yet opened the buildings. Suddenly—the wind changed and blew the well-meant grass-fire up against the building. We lost our theatre. We also lost ten rooms and lost our dining room. There was not a dollar of insurance. But we are gradually making it much better now. The neighbors came, enjoyed the scene; they all came and sat on the grass and watched it—as they might—with pleasure? It wasn't costing them anything. There was no insurance.

Pardon this poignant—perhaps pointless—digression. The point I came here to make to you tonight concerned Science *versus* Art. Until we—the people—make the needed synthesis between them and these two become as one—yes—until the religionist and the artist and the scientist can stand up, understanding each other to work together, the one unwilling to proceed without the other, then only will we have a culture worthy the name. Then only will we be somebody in our own right. We will not then be political in the nonsensical sense that we are now political. (I'm from Wisconsin.) So I think that the situation

in which our America finds itself at the present time, though bad enough architecturally, bad enough artistically, is politically a profanity.

Yes, ladies and gentlemen, this is a serious occasion. Here you come upon matter more serious than you may imagine. Here you really have come to put your own finger upon the center of our fault and upon the very center, too, of our hope. Because we do have hope in this nation today, although our hope has been superficially assumed and often mistaken, too often run off as some fashion in this or that direction or run off as a silly faction in that or another direction—still—I say, we do have the center-line of a true Democratic culture in what is properly called Organic-architecture. That philosophy is something you may now learn to know. You have seen what is now called Modern Architecture. That is merely contemporary. It isn't truly modern, that is to say most of it isn't; very little of it is truly modern. Most of it is merely contemporary along the lines of prevalent fashion. Most of it—too—is going to disappear and be hateful tomorrow, generally speaking—even the better class of residence made in that vein, is already hateful as those red groups of prison-buildings in New York City, Los Angeles (I guess you've got them in Philadelphia too)—or soon will have them if you buy insurance. Hateful as they are, and inhumane. Now I believe Architecture to be the *humanizing* of building. The more humane, the more rich and significant, inviting and charming your architecture becomes, the more truly is it the great basis of a true Culture. Unless it is true architecture in this sense, the less it's architecture at all. May I ask you what those qualities in a building are that make that quality of humanity a possibility or probability? Certainly it would have nothing in common with what we call "housing," would it? It certainly would have nothing in common with anything we could properly call a Style. The Colonial style, of course, is not really a style, but it was colonial. Truth to say, it was Italian architecture Frenchified by English adoption and came over in the *Mayflower* to our shores. We got it as inheritance. So far, so good. Why not? We had no culture of our own whatsoever. It was the best thing we could get, probably, certainly the best thing we could do at the time. But why now? As a prosperous nation we have been "in business" some 160 years; isn't it time we got something finer, deeper, more characteristic, more truly democratic than the hangovers of an old aristocracy? America must build, and *democracy* must build if America builds. Now Democracy has already started building. An organic architecture is ours. If you'll take time to study the center line of the philosophy of an organic architecture, you will find you've got the center-line of the democratic faith and spirit of this nation. See how many of you know it already. But you are going to know more of it and you're going to know it soon. Knowledge of its principles must break into the ranks of education—somehow, somewhere.

Now this may not be in our great universities. It may be that we'll have to take Architecture away from the universities, even take it away from the professional-architects and turn it over to boys that really know how to build something—the contractors? Then God help architecture! Well, ladies and gentlemen of Philadelphia, I am extremely gratified—(I was about to say honored but that word is of dubious origin. I won't use it.) As an Artist, I am pleased by this token of esteem by way of Science. As an architect, I want to raise my hand to salute the memory of a great man, *Benjamin Franklin.*

NOTES FROM THE NATIONAL BUREAU OF STANDARDS *

RAPID-RESPONSE HYGROMETER

An improved electric hygrometer of high sensitivity and extremely rapid response has been designed and constructed by Arnold Wexler, Albert Krinsky, and associates of the National Bureau of Standards Mechanical Instruments Laboratory. Like some previous hygrometers, the device depends on the change in electrical resistance of a salt film with the change in the humidity of the surrounding air. Performance studies indicate that the improved instrument will be particularly well suited to aerological work. This development is the result of work in humidity research being carried out as a part of a program in aerological instruments sponsored at NBS by the Aerology Branch of the Navy's Bureau of Aeronautics. The improved instrument is now undergoing further development.

Development of the improved hygrometer was undertaken because of the pressing need in meteorological science for more accurate humidity data on the upper air. The hygrometer now employed in radiosonde flights consists of a flat strip of polystyrene having sputtered tin electrodes on the two long edges and coated with an electrolytic film of aqueous lithium chloride dissolved in a plastic binder. One of the basic limitations of this type of hygrometer is its relatively slow speed of response, particularly at low temperatures. A radiosonde flight may reach 80,000 feet, and the greater portion of the ascent will be at low temperatures. At the rate of balloon ascent now employed—1000 feet per minute—and the even greater rates that are contemplated, slow response in the humidity element introduces an uncertainty in the interpretation of the data. It is expected that the more rapid response of the Bureau's improved hygrometer will make possible increased accuracy and reliability in aerological measurements.

In preliminary experiments at the Bureau it was found that the response limitations of the lithium chloride hygrometer are principally due to the relatively long time required for the water vapor in the air to diffuse into or out of the plastic binder and to thereby change the concentration of the lithium chloride solution. An effort was therefore made to develop an electric hygrometer which would depend on the physical adsorption of water vapor on a film surface rather than the slower process of absorption within the film layer. Experiments with various types of materials eventually led to a rapid-response hygrometer consisting of an extremely thin film of a salt, such as potassium dihydro-

* Communicated by the Director.

gen phosphate, evaporated under vacuum on a specially treated flat strip of glass or other insulating material. Water vapor is rapidly adsorbed on the surface of the film and reaches its equilibrium concentration very quickly. An electronic circuit measures the resistance of the film, providing a continuous record of humidity.

Thus far, experimental studies of the rapid-response instrument have been concerned primarily with the size and material of the insulating blanks, the treatment of the uncoated blanks, the configuration and spacing of the electrodes, the thickness of the deposited salt film, and the chemical nature of the salt. Two base materials have been studied: glass and polystyrene sheet. To remove any free alkali which might possibly contaminate the salt film, the glass has usually been treated by washing with detergent and water, rinsing in benzol, and leaching in nitric acid at 80° C. for one hour. The polystyrene is treated by washing with soap and water and rinsing in benzol.

Several variations of the basic design have been constructed. One type which shows considerable promise uses glass blanks 3 × 11/16 × 1/32 in. in size. After the surface has been leached and cleaned, silver electrodes 1/16 in. wide are sprayed onto the long edges and the glass blanks are then fired. The blanks are annealed during the firing operation. They are then cleaned once more and are placed in a vacuum chamber, where potassium dihydrogen phosphate is deposited on one surface by evaporation. The thin film thus formed adheres tenaciously to the glass.

The logarithm of the resistance of the film is essentially a linear function of relative humidity. The range of resistance extends over six decades, decreasing with increasing relative humidity; at very low humidities the resistance is of the order of 10^{12} ohms. The problem presented by the generally high resistance of the film was solved by the design of an electrometer tube circuit which subjects the hygrometer to a maximum current loading of 100 microamperes. The output of this circuit, which may either be read on a meter or fed into a recorder, varies linearly with the logarithm of the input resistance. The net result is that an output approximately linear with relative humidity is obtained.

On this hygrometer, a 63-per cent change in indication, caused by a sudden change in relative humidity, takes place in less than ½ second at room temperature and in about 10 seconds at −20° C. In comparison with the standard hygrometer element in current use, this represents a 24-fold increase in speed of response at room temperature and a 13-fold increase at −20° C.

Investigation of the performance characteristics of the Bureau's hygrometer is continuing. The effects of such factors as temperature, polarization, exposure to high humidity, and aging are being determined. Other materials are also being investigated to determine their suitability as hygrometer elements.

HYDRAULIC-TURBINE DENTAL HANDPIECE

A hydraulic-turbine dental handpiece which attains a speed of 61,000 revolutions per minute has been developed at the National Bureau of Standards. At this speed, very low cutting pressure is required and dental enamel can be cut rapidly with a minimum of vibration and heating. By positioning the turbine in the head of the handpiece and connecting it directly to the cutting tool, the mechanical difficulties involved in the use of high rotational speeds with the conventional belt-and-gear propelled cutting tools have been eliminated. Besides making possible more efficient cutting of tooth structures and reducing the time spent by the patient in the dental chair, the hydraulic-turbine handpiece[1] also promises to be of considerable utility in other fields where small amounts of hard materials must be removed by grinding, as in tool and die making.

The hydraulic handpiece was designed and constructed by Dr. R. J. Nelsen, of the American Dental Association Research Fellowship at the Bureau, and C. E. Pelande and J. W. Kumpula of the NBS staff. The project was part of a program of dental research which NBS is conducting in cooperation with the American Dental Association and the dental services of the Army, the Air Force, the Navy, and the Veterans' Administration.

At present the maximum speed of conventional dental cutting instruments is about 6500 rpm. Because of the small size of dental burs, this rate of rotation gives too low a linear speed for efficient cutting of tooth structures. For example, a steel bur can remove the same amount of material in four seconds at 12,000 rpm. as it can in approximately 30 seconds at 2000 rpm.[2] However, in spite of the disadvantages of using low rotational speeds, dentists have hesitated to use higher speeds with the conventional gear-type handpiece because of the excessive vibration and heat development and the potential hazard to the patient caused by the high inertia of the revolving instrument.

Several types of dental rotary cutting instruments using air or water as the motive power have been constructed in the past, but each of these was designed for the straight dental handpiece, and each required that a gear-type contra-angle handpiece be attached. The instrument developed at NBS is designed to completely eliminate gears within the handpiece since the turbine is placed in the head of the contra-angle. This makes it possible to overcome many of the disadvantages of high rotary speed in cavity preparation by taking advantage of the smoothness and other characteristics inherent in hydraulic systems. Thus, vibration is minimized; and the high-speed stream of

[1] For further technical details, see "Hydraulic Turbine Contra-angle Handpiece," by Robert J. Nelsen, Carl E. Pelander, and John W. Kumpula, *J. Am. Dental Assoc.*, Vol. 47, p. 324 (1953).

[2] "Temperatures Developed in Rotating Dental Cutting Instruments," by Donald C. Hudson and William T. Sweeney, *J. Am. Dental Assoc.*, Vol. 48, p. 127 (1954).

fluid passing over the turbine and shaft acts as a coolant so that overheating is prevented in spite of the high rotational speed developed.

A further advantage of the hydraulic handpiece is that even while rotating at top speed, the cutting instrument can be stopped immediately by placing a finger abruptly against its edge. Then, as soon as the disk is released, it will start rotating again. This means that if the operator should press too heavily on the cutting tool or if the tool should happen to catch or bind in some manner that would be hazardous with the ordinary handpiece, the hydraulic instrument will automatically stop rotating. Because of the extremely light pressures used for cutting, there is considerably less strain on the operator. Furthermore, the cutting tools do not climb or roll out of the cavity as do those used in the slower rotating instruments. While some adjustment in the dentist's operating procedure is necessary, the instrumentation is basically the same as his present methods, and therefore the dentist requires no special training in its use.

The over-all size and shape of this handpiece are within the general proportions of the conventional gear-driven contra-angle handpiece. The turbine shaft is designed so that the hollow shaft of the cutting instrument fits over it. A spring key attachment on the turbine shaft fits into a keyway in the cutting-instrument shaft, and the centrifugal force developed by the rotating turbine causes this spring to lock the cutting instrument in place. When the shaft is still, the cutting instrument can be easily attached or removed.

The turbine has six notched blades fixed to the shaft and measures 7.5 mm. in diameter and 4.8 mm. in length. Although steel ball bearings have been used in some models, they are rather harsh and noisy in this application. Various combinations of low-friction plastic materials in bearings and journals have proved much more satisfactory as they are quieter in operation and do not require lubrication.

The associated hydraulic system consists of a mobile cabinet which contains a fluid pumping mechanism, a reservoir tank, a pressure switch, a solenoid valve, and distribution lines. The contra-angle handpiece is connected to a flexible coaxial double tubing. The $\frac{3}{8}$-in. inside tube carries the propellent fluid (water under pressure to the contra-angle handpiece while the $\frac{5}{8}$-in. outer tube carries the spent fluid back to the reservoir. The tubes join with the direct line from the pump and the line to the reservoir tank. A constant-volume pump, close-coupled to a $\frac{1}{2}$-hp. electric motor, is used. To minimize undesirable motor noise, the pumping equipment is enclosed in a sound-insulated cabinet.

The unit is self-contained and needs only to be connected to an electrical outlet for operation. The fluid is stored in the reservoir and is used over and over; hence the unit requires no adjustment during normal use. To stop the turbine momentarily, the operator steps on

a special tube containing fluid. The force exerted closes a pressure switch, thus opening a solenoid valve which allows the propellent to bypass the turbine and to return directly to the reservoir. While the instrument is being used, the motor and pump operate continuously and the handpiece is energized as needed by the operator. The motor is controlled by a switch located on the side of the unit.

Grinding tools such as points and disks of diamond and silicon carbide have been found to cut with exceptional efficiency when used with the hydraulic handpiece. However, milling cutters like the steel and carbide burs of current design do not function well at such extremely rapid rates of cutting. It is believed that the design of the cutting blades of all burs will have to be modified before they can be used at the rotational speeds of this handpiece.

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CHARLOT, GASTON; BÉZIER, DENISE AND GAUGUIN, ROLLAND. Rapid Detection of Cations. 1954.

GREAT BRITAIN. MINISTRY OF SUPPLY. Adhesives. 1952.

GREAT BRITAIN. MINISTRY OF SUPPLY. Ceramics and Glass. 1952.

GREAT BRITAIN. MINISTRY OF SUPPLY. Lubricants and Lubrication. 1952.

GREAT BRITAIN. MINISTRY OF SUPPLY. Paints. 1952.

HARPER, JAMES I., ED. Chemical Engineering in Practice. 1954.

LIPATOW, S. M. Physikalische Chemie der Kolloide. 1953.

NOBLE, ROYCE J. Latex in Industry. Ed. 2. 1953.

RIETEMA, KORNELIS. Study on the Compressibility of Filter Cakes. 1952.

ROYALS, E. EARL. Advanced Organic Chemistry. 1954.

SCHUNCK, HERMANN. Thermodynamische Grundlagen der Physikalischen Chemie. 1953.

SKINNER, GORDON; JOHNSTON, HERRICK L., AND BECKETT, CHARLES. Titanium and its Compounds. 1954.

SPECHT, FRANZ. Quantitative Anorganische Analyse in der Technik. 1953.

VAN DEN TEMPEL, MACARIUS. Stability of Oil-in-Water Emulsions. 1953.

WIIG, EDWIN O.; LINE, WILLARD R.; AND FLAGG, JOHN F. Semimicro Qualitative Analysis, a Course in Applied Chemical Equilibrium. 1954.

ELECTRICITY AND ELECTRICAL ENGINEERING

AGGER, LEE THOMAS. Principles of Electronics. 1953.

AUSTRALIA. COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH. RADIOPHYSICS LABORATORY. A Textbook of Radar. Ed. 2. 1954.

BORG, H. Théorie des Circuits Impulsionnels. 1953.

BUKSTEIN, EDWARD J. The Magic of Electronics. 1954.

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VILBIG, FRIEDRICH. Hochfrequenz-Messtechnik. 1953.

ENGINEERING

CAMM, FREDERICK JAMES, ED. Newnes Engineers Reference Book. Ed. 6. 1954.

SINGER, FERDINAND LEON. Engineering Mechanics. Ed. 2. 1954.

VER PLANCK, DENNISTOUN WOOD AND TEARE, BENJAMIN RICHARD, JR. Engineering Analysis. 1954.

INDUSTRIAL MANAGEMENT

OWENS, RICHARD N. Management of Industrial Enterprises. Rev. Ed. 1953.

MANUFACTURE

MACHU, WILLI. Moderne Galvanotechnik. 1954.

SCHULENBURG, A. Betriebspiaxis der Metallgiesserei. 1953.

MATHEMATICS

BLACKWELL, DAVID AND GIRSHICK, M. A. Theory of Games and Statistical Decisions. 1954.
BOWDEN, B. V., ED. Faster than Thought; a Symposium on Digital Computing Machines. 1953.
DEGRAZIA, JOSEPH. Math Is Fun. 1954.
GRIFFIN, HARRIET. Elementary Theory of Numbers. 1954.
HAAR, D. TER. Elements of Statistical Mechanics. 1954.
HAY, G. E. Vector and Tensor Analysis. 1953.

MECHANICAL ENGINEERING

CASE, RICHARD Y. "Timing" Belt Drive Engineering Handbook. 1954.
DEURING, KARL. Spannen im Maschinenbau. 2 Aufl. 1953.
DOUGHTIE, VENTON LEVY AND JAMES, WALTER H. Elements of Mechanism. 1954.

METALLURGY

BRICK, ROBERT MAYNARD; LOW, JOHN ROUTH, JR.; AND LORIG, CLARENCE HERMAN. Behavior of Metals at Low Temperature. 1953.

PHYSICS

ADIROWITSCH, E. I. Einige Fragen zur Theorie der Lumineszenz der Kristalle. 1953.
DUHEM, PIERRE MAURICE MARIE. The Aim and Structure of Physical Theory. 1954.
FUHRMANN, ARWED. Aufgaben aus Analytischen Mechanik. 2 Aufl. 1879.
INGERSOLL, LEONARD ROSE; ZOBEL, OTTO J.; AND INGERSOLL, ALFRED C. Heat Conduction. Rev. Ed. 1954.
MARCOLONGO, ROBERTO. La Meccanica di Leonardo da Vinci. 1932.
RITTER, A. Lehrbuch der Höheren Mechanik. Ed. 3. Pt. 1, 3. 1899.
SYNGE, J. L. Geometrical Mechanics and De Broglie Waves. 1954.
ZWIKKER, C. Physical Properties of Solid Materials. 1954.

SCIENCE

KANTOR, J. R. The Logic of Modern Science. 1953.

SCIENTIFIC INSTRUMENTS

CHEVALLIER, JEAN GABRIEL AUGUSTIN. Essai sur l'Art de l'Ingenieur en Instrumens de Physique Expérimentale. 1819.

JOURNAL OF THE FRANKLIN INSTITUTE

The following papers will appear in this JOURNAL within the next few months:

LEVITT, I. M.: The Hydrogen Bomb.

SCHONLAND, B. F. J. AND D. J. MALAN: Upward Stepped Leaders from the Empire State Building.

TEA, PETER L.: A String Net Analog for the Numerical Solution of the Equation of Laplace, and of Poisson.

SEYMOUR, D. W. AND W. F. G. SWANN: A Determination of μ-Mesotron Rest Lifetime and a Verification of the Relativistic Expression for Variation of Lifetime with Momentum.

SCARLOTT, C. A.: Wind Tunnels—Why and Where.

BACON, LESLIE R. AND JOHN H. WILLS: pH-Composition Relations in the System $Na_2O-SiO_2-H_2O$ at 20°C.

LANGHAAR, H. L. AND M. STIPPES: Three-Dimensional Stress Functions.

WATHEN, ROBERT L.: The Traveling Wave Tube—A Record of Its Early History.

SWANN, W. F. G.: The Acquirement of Cosmic Ray Energies by Electromagnetic Induction in Galaxies.

MOON, PARRY AND DOMINA EBERLE SPENCER: Photometrics in Astronomy.

NOTES FROM THE BARTOL RESEARCH FOUNDATION

W. F. G. SWANN, DIRECTOR

GAMMA RAYS FROM PROTON CAPTURE IN LITHIUM*

BY

C. E. MANDEVILLE, M. A. ROTHMAN, W. C. PORTER, AND C. P. SWANN

The large Van de Graaff generator has been engaged in the study of reactions induced in the nuclei of light elements by protons of energies in the range 1.5 to 5 Mev. The yield of gamma rays from the reaction $Li^7 + p \rightarrow Be + \gamma$-rays has been measured over this range. By means of a scintillation counter and pulse height analyzer, it has been possible to select for measurement the well-known 14.8 and 17.6 Mev γ-rays. It is found that the yield of these γ-rays shows a broad peak at 2.1 Mev, the presence of which has previously been in question. Preparations are being made to measure the angular distribution of these γ-rays in the neighborhood of the resonance.

* Assisted by the Joint Program of the U. S. Office of Naval Research and the U. S. Atomic Energy Commission.

ANGULAR DISTRIBUTION OF ELASTICALLY SCATTERED NEUTRONS *

BY

S. C. SNOWDON AND H. S. HANS

For the purposes of measuring the angular distribution of neutrons elastically scattered from various elements, in particular Cu, Zn, Zr, and Mo, a preliminary survey of scintillating materials is being undertaken with the object of preparing a photomultiplier detector that will register only the most energetic neutrons (3.7 Mev, in our case) and reject lower energy neutrons and any γ-rays that accompany the neutron scattering process.

* Assisted by the U. S. Atomic Energy Commission.

FORMULATION OF THE QUANTUM MECHANICAL COLLISION PROBLEM *

BY

LEONARD EISENBUD

The usual textbook treatment of collisions in quantum mechanics pays for its advantage of formal simplicity by, (1) employing methods which are not strictly orthodox—the non-normalizable wave function and the probability current, and (2) by employing a description of the

collision process which, on first view, at least, is almost unrecognizably different from the process as it occurs in the laboratory. Both defects of the standard treatment are readily remedied by employing a time dependent treatment which makes use of normalized state functions. The initial condition of the system is recognized as a "mixture" but it is easily seen that this gives rise to no complications. The time dependent analysis permits a more detailed picturization of the collision process. It also reveals that the phase shift controls not only the cross sections but also the time dependent properties of the collision, that is, the extent to which the scattered wave is delayed in the course of the interaction.

* Assisted in part by the Joint Program of the U. S. Office of Naval Research and the U. S. Atomic Energy Commission.

POLARIZATION AND ELECTROLYSIS IN THORIUM OXIDE CRYSTALS *

BY

W. E. DANFORTH

As a first stage in the study of critical disintegration phenomena in thorium oxide crystals, we are investigating the current-voltage-time behavior of the system Pt–ThO_2–Pt. Maintenance of a time-independent current between the platinum electrodes is accompanied by an emf which rises to many times its original value. On cessation of the current, this polarization decays according to a time function which is similar to the rising function but not identical. As the current parameter is increased the polarization appears to limit itself at 0.35 volt, a phenomenon believed associated with onset of electrolysis. At 1300° C., and for voltages below the critical value, hours are required for equilibrium to be established.

Interpretation of polarization experiments with thorium oxide crystals requires mathematical analysis of a system which conducts both by electrons and by ions. Analysis of the curves of growth and decay of polarization should yield information regarding numbers and mobilities of ionic carriers. Where space charge is treated exactly, the expressions become exceedingly cumbersome; the assumption of electrical neutrality greatly simplifies the problem, although the validity of this assumption requires proof in each case. With reference to our experiments with thorium oxide, it has been shown that the high values of polarization require a number of mobile positive ions in excess of the number of mobile electrons, charge equality being maintained by negative ions fixed in the lattice. The mathematical work is being carried on by J. H. Bodine.

* Assisted by the U. S. Navy Bureau of Ships and by the U. S. Office of Ordnance Research.

DEPENDENCE OF SECONDARY ELECTRON EMISSION UPON ANGLE OF INCIDENCE OF PRIMARY BEAM *

BY

M. A. POMERANTZ, J. F. MARSHALL AND R. A. SHATAS

Utilizing the sandwich arrangement for determining the yield of secondary electrons from the two faces of a thin target bombarded by 1.3 Mev primaries, measurements have been obtained as a function of the angle between the normal to the surface and the direction of the beam. This is accomplished by rotating the electrode assembly inside the continuously-pumped demountable experimental tube.

Preliminary experiments have revealed that the yield depends upon the length of path traversed by the primaries as they pass through the target, and the following relationship is consistent with the observations thus far:

$$\delta_{\theta^\circ}/\delta_{0^\circ} = \sec\theta.$$

These investigations are being continued.

* Assisted by the U. S. Office of Ordnance Research.

NOTES FROM THE FRANKLIN INSTITUTE MUSEUM

A. C. CARLTON, DIRECTOR

"TACONIC": COMMAND SHIP

A great many of the visitors to the Marine Section of the Museum have never been to sea and have no intention of ever going, but this limitation in experience does not diminish their interest in the models of ships, new and old. There is a fascination about ships which is quite understandable, for a full rigged ship is surely one of man's greatest accomplishments. Some of the romance of the sea is missing from the clumsy early efforts to secure independence from white canvas by utilizing steam to give the ship propulsion. Now, however, romance of another kind is attached to certain types of ships. The latest addition by the United States Navy to its display in the Marine Section epitomizes this newly romantic element.

This latest contribution is a superb model of the U. S. S. *Taconic*, some nine feet in length. The original ship is designed to be a command ship and, as such, is the communication center for a naval force. The superstructure of the vessel is an amazing complication of antennae, of which there are no less than seventy, offering an overhead pattern as intricate as the rigging of a fully rigged ship of the old days.

While this unusually handsome model (which, by the way, was built at the Philadelphia Navy Yard) will doubtless be admired as a specimen of the model maker's art, it should also serve to remind visitors of the part played by the Naval Research Laboratory in the development of radar, which is a conspicuous part of the *Taconic's* equipment. Because radar played such an important part in the defense of Great Britain during the savage air attacks of World War II it has been gratuitously assumed that the British had developed the system and that the United States had necessarily borrowed from them. While in no way seeking to detract from the work of Sir Robert Watson-Watt and his collaborators whose independent work led to the devising of their efficient system, the effort of the Naval Research Laboratory in this field cannot be overlooked.

This actually began in 1922 when Dr. A. Hoyt Taylor and Leo C. Young noticed in receiving radio signals transmitted across the Potomac River on a 5-meter wave-length, a distortion of the signals when a vessel was in the vicinity of the transmitter or receiver. This observation led to the pursuit of investigations into wave propagation. In 1930, Young and L. A. Hyland observed that an airplane could cause interference with reception and they promptly perceived the possibility of

radio detection of planes. By 1932 Taylor had worked out a complete system of anti-aircraft defense, using only the equipment available at the time. The first pulse radar system was built at the Laboratory in 1934 and put to the test in December of that year.

This gave such promising results that further research in the field was encouraged, and work was started on a 200 megacycle radar system. This was put into operation, with transmitter and receiver working through the same antenna, in October 1936. This was the set that was put to a practical sea test on the *Leary* in the following April with completely satisfactory results. The success achieved led to the further development of the famous XAF high power search radar set that was operated on the *New York* in December, 1938, and is usually quoted as the first demonstration of radar in the United States, to the exclusion of all the preliminary work.

The first radar set on shipboard had a large rotating antenna about seventeen feet square that was known as the "flying mattress," and was regarded with horror by those officers who set great store upon the trim appearance of their ships. It would be interesting to know what those officers would think of the *Taconic* and her class, for the numerous antennae give the vessels the appearance of being floating laboratories, but they serve to illustrate the great advances that have been made in radar and communication systems in general since the Naval Research Laboratories put their first radar set on board of the *Leary* seventeen years ago.

NOTES FROM THE FRANKLIN INSTITUTE LABORATORIES FOR RESEARCH AND DEVELOPMENT

NICOL H. SMITH, DIRECTOR

NEW METHOD OF MEASURING ELASTIC AND PLASTIC STRAINS IN A SURFACE

BY

R. C. GOOD, JR.

Many items are produced by extruding soft metals into symmetrical shapes. Their meridional planes usually exhibit plane strain during deformation. We study processes of that character by taking data from those planes (1). Because plane strain exists when the points do not move perpendicular to that plane, we can use a billet split down the center to create that plane without affecting the process. If a grid is lightly inscribed on the inner surfaces of the billet, point displacements can be measured at the shifted grid intersections.

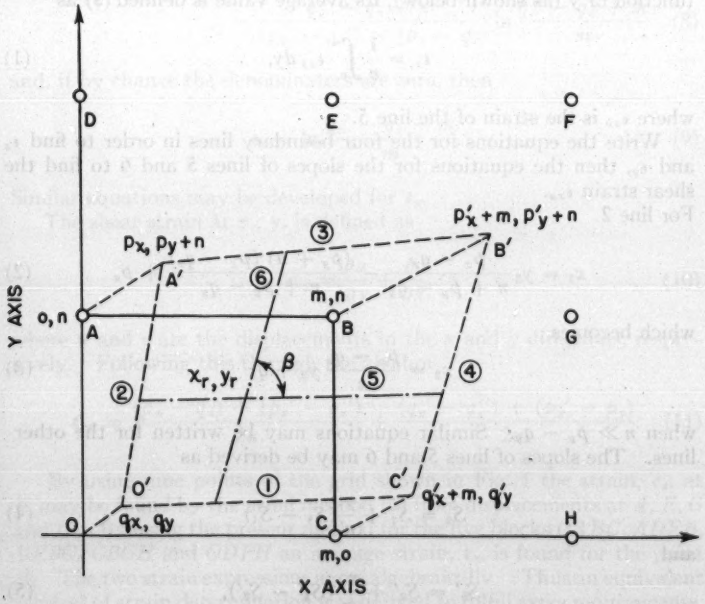

FIG. 1. Plastic displacements of the unit rectangle.

Usually the strains at an intersection point on the grid are found from displacements at the four nearest points (2). The method to be described uses data from four corners of a unit rectangle of the grid to find the average strain over that area.

There are at least three advantages: the effective spacing of the grid is decreased, the strains at the edge of the specimen can be obtained, and the derived strain is that of an area rather than that at a point. The grid is assumed small enough for straight lines to remain straight lines, and no large strains occur within the rectangle so that the average strain of the area is meaningful.

Figure 1 shows the unit rectangle in the first quadrant with its corners having the coordinates o, o; o, n; m, n; and m, o. During plastic flow these points are shifted to q_x, q_y; $p_x, p_y + n$; $p_x' + m, p_y' + n$; and $q_x' + m, q_y'$. The p's and q's may be found by measuring the deformed grids. The line numbers in circles 1, 2, 3 and 4 are the displaced sides of the unit rectangle. And the lines 5 and 6 are representative lines for linear strain calculation which sweep through the quadrangle during integration. The intersection point x_r, y_r forms the angle β from which the shear strain is obtained. If the strain in the x direction, ϵ_x, is a function of y (as shown below), its average value is defined (3) as

$$\bar{\epsilon}_x = \frac{1}{n}\int_0^n \epsilon_{x5}\, dy, \tag{1}$$

where ϵ_{x5} is the strain of the line 5.

Write the equations for the four boundary lines in order to find ϵ_x and ϵ_y, then the equations for the slopes of lines 5 and 6 to find the shear strain ϵ_{xy}.

For line 2

$$x_2 = y_2 \frac{p_x - q_x}{n + p_y - q_y} - \frac{(p_y + n)(p_x - q_x)}{n + p_y - q_y} + p_x \tag{2}$$

which becomes

$$x_2 = \frac{p_x - q_x}{n} y_2 + q_x \tag{3}$$

when $n \gg p_y - q_y$. Similar equations may be written for the other lines. The slopes of lines 5 and 6 may be derived as

$$S_5 = S_1 + \frac{y_r}{n}(S_3 - S_1) \tag{4}$$

and

$$S_6' = S_2' + \frac{x_r}{m}(S_4' - S_2'), \tag{5}$$

where S is $\frac{dy}{dx}$ and S' is $\frac{dx}{dy}$.

For elastic strains $\epsilon_x \equiv \frac{\Delta m}{m}$, where $\Delta m = x_4 - x_2 - m$. After substituting for x_2 and x_4, from Eq. 1 one finds

$$\bar{\epsilon}_x = \frac{(p_x' - p_x) + (q_x' - q_x)}{2m} \tag{6}$$

and similarly

$$\bar{\epsilon}_y = \frac{(p_y' + p_y) - (q_y' + q_y)}{2n}. \tag{7}$$

For large strains in the plastic region $\epsilon_x \equiv \ln \frac{m + \Delta m}{m}$, where ln is the natural logarithm. Following this through the algebra one finds that

$$\bar{\epsilon}_x = \frac{p_x' - p_x + m}{(p_x' - q_x') - (p_x - q_x)} \ln \frac{p_x' - p_x + m}{m} - 1 - \frac{q_x' - q_x + m}{(p_x' - q_x') - (p_x - q_x)} \ln \frac{q_x' - q_x + m}{m} \tag{8}$$

and, if by chance the denominaters are zero, then

$$\bar{\epsilon}_x = \ln \frac{q_x' - q_x + m}{m}. \tag{9}$$

Similar equations may be developed for $\bar{\epsilon}_y$.

The shear strain at x_r, y_r is defined as

$$\epsilon_{xy} = \frac{\partial u}{\partial y} + \frac{\partial v}{\partial x}, \tag{10}$$

where u and v are the displacements in the x and y directions, respectively. Following this through the algebra

$$\bar{\epsilon}_{xy} = \frac{(p_x - q_x) + (p_x' - q_x')}{2n} + \frac{(q_y' - q_y') + (p_y' - p_y)}{2m}. \tag{11}$$

By using nine points of the grid shown in Fig. 1 the strain, ϵ_x, at B may be found by the usual method (2) from displacements at A, E, G and C. By using the present method for the five blocks $OABC$, $ADEB$, $BEFG$, $CBGH$ and $ODFH$ an average strain, $\bar{\epsilon}_x$, is found for the point B. The two strain expressions agree algebraically. Thus an equivalent method of strain determination was derived to fulfill extra requirements.

Researchers at The Franklin Institute who developed this technique used it successfully.

The author acknowledges the financial support of the U. S. Army Ordnance Corps which made this work possible.

BIBLIOGRAPHY

(1) C. T. YANG AND E. G. THOMSON, "Plastic Flow in a Lead Extrusion," ASME paper No. 52-F-18, October 1952.

(2) S. TIMOSHENKO AND J. N. GOODIER, "Theory of Elasticity," New York, McGraw-Hill Book Co., Inc., 1951, p. 461.

(3) R. S. BURINGTON AND C. C. TORRANCE, "Higher Mathematics," New York, McGraw-Hill Book Co., Inc., 1939, p. 224.

NOTES FROM THE BIOCHEMICAL RESEARCH FOUNDATION

ELLICE McDONALD, DIRECTOR

PROTEIN-DEPLETION AND AGE

BY

M. H. ROSS AND J. O. ELY

The effect of a protein-free diet on the activity of hepatic enzymes was investigated in normal adult rats. The enzyme activity of the adult protein-depleted rat was found to be strikingly similar not to that of the adult or old adequately fed rat but to that of the young rat.

Adult, 5 to 6 months old, male Wistar strain rats weighing 160 to 170 g. were used. They were maintained on the stock diet, Purina Laboratory Chow [crude protein (min.) 23%, crude fat (min.) 5%, crude fiber (max.) 6%, nitrogen-free extract (min.) 44%] or on a protein-free—high-carbohydrate ration [corn oil 5%, dextrose 89%, salt mixture 4%, rice bran extract (Vitab) 2%, riboflavin 0.002%] for 30 days. The caloric intake of the rats fed the protein-free diet was nearly as great as that of those fed the stock diet; the former ingested approximately 13 g. (50–55 calories) daily and lost approximately 40% of their body weight during the 30 days they were fed the diet, whereas the latter ingested approximately 15 g. (60–65) calories daily.

The methods used were identical to those reported (1).

A decrease was found in the enzyme activity of 8 individual enzymes studied in the liver homogenates of adult protein-depleted rats, and an increase in 2; one remained unchanged (Table I). A decrease was found in oxygen uptake and in fructolysis of fresh liver slices (Table II). The activity level of all of these hepatic enzymes and enzyme systems was observed to be like that of the young adequately fed rat (1). It was noted that when the enzyme activity of the young rat was high, the value for the protein-depleted rat was higher and when the enzyme activity was low, that of the protein-depleted rat was lower. If the activity did not change with age, it did not change with protein depletion.

This change of enzyme value to that of the young animal by protein depletion can also be seen by comparing the findings of others. Rat liver arginase (2), xanthine oxidase (3), succinoxidase (4), and transaminase (5) were reported to increase during ageing, and to decrease (2, 6, 7, 8) during protein depletion. Cytochrome oxidase was reported to decrease during ageing (9) and to increase during protein depletion (10).

Similarities were found, too, in the nitrogen content, cell and mitochondria count (Table III), and in the changes in organic phosphate, ATP, and glycerophosphate fraction of the liver (11).

TABLE I.—*Enzyme Activity of Fresh Liver Homogenates of Adult Normal and Protein-Depleted Rats.*

	Units	No. of Rats	Adequately Fed Rat	Protein-Depleted Rat
Adenosinetriphosphatase	ATPase units			
Without Ca^{++}		25	1.90±0.22	1.32±0.25
With Ca^{++}		25	6.88±0.29	3.04±0.22
Pyrophosphatase	γP liberated/mg. liver/15 min.	31	17.05±0.68	1.74±0.63
Acid phosphatase	γP liberated/mg. liver/hr.	97	14.57±0.16	14.63±0.45
Alkaline phosphatase	γP liberated/mg. liver/hr.	80	1.09±0.09	2.22±0.25
Dehydrogenase without added substrate	γ Formozan produced /mg. liver/10 min.	30	0.31±0.02	negligible
Succinic dehydrogenase	γ Formozan produced /mg. liver/10 min.	36	1.09±0.03	0.31±0.02
Lactic dehydrogenase	γ Formozan produced /mg. liver/10 min.	52	0.66±0.02	0.03±0.01
Malic dehydrogenase	$\mu l. O_2$/mg. liver/hr.	33	17.10±0.37	7.05±0.63
l(−) Histidase	Histidase units /g. liver	32	1.42±0.04	0.40±0.05
Cathepsin	$(C.u.)^{hb} \times 10^{-4}$	37	9.92±0.38	11.85±0.61
D-Amino oxidase	$\mu l. O_2$/mg. liver/hr.	14	287.6 ±10.7	62.5 ±4.24
Fructokinase	mg. fructose disappeared/100 mg. liver/30 min.	20	0.88±0.04	0.45±0.04

TABLE II.—*Enzyme Activity in Fresh Liver Slices of Adult Normal and Protein-Depleted Rats.*

	Units	No. of Rats	Adequately Fed Rat	Protein-Depleted Rat
Oxygen uptake				
With no added substrate	$\mu l. O_2$/hr./mg. liver	58	1.20±0.03	0.41±0.03
With sodium succinate 0.05 M final concentration	$\mu l. O_2$/hr./mg. liver	26	2.97±0.10	2.79±0.09
Autoglycolysis	$\mu l. CO_2$/hr./mg. liver	27	0.86±0.07	0.27±0.03
Fructolysis				
Fructose 0.015 M final concentration	$\mu l. CO_2$/hr./mg. liver	27	1.16±0.05	0.18±0.06

TABLE III.

	Adequately Fed Rat	Protein-Depleted Rat
Total nitrogen, mg./100 mg. fresh liver	2.91±0.025	2.21±0.004
Moisture content, %	70.6 ±0.16	70.9 ±0.43
Total nuclei per microscopic field	196.4 ±3.8	305 ±8.6
Hepatic nuclei per microscopic field	115.6 ±2.8	163.0 ±8.4
Mitochondria ($\times 10^{-10}$)/g. fresh liver	12.0 ±0.5	5.3 ±0.6
Mitochondria per nucleus	623 ±39	155 ±16

Because of the drastic unbalanced dietary regime, the expected loss in body weight occurred. It was shown by McCay (12) that when growth was limited by a carbohydrate or caloric restriction, the life span was prolonged. A limitation of growth by a reduction in protein intake may also contribute to lengthening of the life span.

SUMMARY

The influence of a protein-free diet on the level of activity of a number of enzymes was investigated in adult rats. The level of activity was found to be similar not to that of the adult or old adequately fed rat but to that of the young rat.

REFERENCES

(1) M. H. ROSS AND J. O. ELY, JOUR. FRANKLIN INST., Vol. 258, p. 63 (1954).
(2) J. MANDELSTAM AND J. YUDKIN, *Biochem. J.*, **51**, 681 (1952).
(3) W. W. WESTERFELD AND D. A. RICHERT, *J. Biol. Chem.*, **192**, 35 (1951).
(4) C. J. KENSLER, M. RUDDEN, E. SHAPIRO AND H. LANGEMANN, *Proc. Soc. Exptl. Biol. Med.*, **79**, 39 (1952).
(5) P. P. COHEN AND G. L. HEKHUIS, *Cancer Research*, **1**, 620 (1941).
(6) G. LITWACK, J. N. WILLIAMS, JR., P. FEIGELSON AND C. A. ELVEHJEM, *J. Biol. Chem.*, **187**, 605 (1950).
(7) N. MILLMAN, *Proc. Soc. Exptl. Biol. Med.*, **77**, 300 (1951).
(8) J. AWAPARA, *J. Biol. Chem.*, **200**, 537 (1953).
(9) H. O. KUNKEL AND J. E. CAMPBELL, JR., *J. Biol. Chem.*, **198**, 229 (1952).
(10) W. W. WAINIO, B. EICHEL, H. J. EICHEL, P. PERSON, F. L. ESTES AND J. B. ALLISON, *J. Nutrition*, **49**, 465 (1953).
(11) N. O. KAPLAN AND D. M. GREENBERG, *Proc. Soc. Exptl. Biol. Med.*, **57**, 130 (1944).
(12) C. M. MCCAY, in "Cowdry's Problems of Ageing," edited by A. I. LANSING, Baltimore, Williams & Wilkins Co., 3rd ed., 1952.

BOOK REVIEWS

WAVE MOTION AND VIBRATION, Volume V, edited by Albert E. Heins. 169 pages, diagrams, 18 × 26 cm. New York, McGraw-Hill Book Co., Inc., 1954. Price, $7.00.

The Fifth Symposium in Applied Mathematics of the American Mathematical Society was held at the Carnegie Institute of Technology in June 1952. All told, fifteen papers were given on Wave Motion and Vibration Theory in four separate sessions: Stability of Fluid Motions, Hydrodynamic Waves, Diffraction and Scattering Problems, and Vibration Theory. The reviewers felt that the readers of this JOURNAL—all potentially buyers of the present volume—will be served best by a brief discussion of some of the papers and mention by title of others.

1. Hydrodynamic Stability, by C. C. Lin, brings to the fore the prevalent controversial points regarding the stability of a viscous fluid subject to infinitesimally small disturbances. Stability is first studied by consideration of linearized equations for small disturbances from the initial flow and by examination of the conditions under which the disturbances increase or decrease. If this linearization process is adopted, some purely mathematical difficulties arise in connection with the characteristic value problem. A discussion of the linearization theory is followed by problems connected with friction layers and friction regions.

2. Examples of the Instability of Fluid Motion in the Presence of a Magnetic Field, by S. Chandrasekhar. This paper deals with hydromagnetic analogs of the thermal instability of a horizontal layer of fluid and of the rotational instability of viscous flow between rotating cylinders; the fluid is thought of as an electrical conductor within a magnetic field.

3. On Free Surface Flows, by P. R. Garabedian.

4. Review of Significant Observations on the Mach Reflection of Shock Waves, by W. Bleakney.

5. On a Nonlinear Differential Equation in Hydraulics, by N. W. McLachlan, treats the solution of $\ddot{u} + 2k|u|\dot{u} + au = d$ which arises in a hydroelectric power system consisting of a reservoir, a surge tank, and pipe lines connecting both with the penstock and the turbines.

6. Acoustic Radiation Pressure on a Circular Disk, by H. Levine.

7. Infinite Matrices Associated with a Diffraction Problem (Abstract) by W. Magnus.

8. On the Coupling of Two Half Planes, by A. E. Heins (Editor of the Series) and H. Feshbach. This paper discusses the coupling of two ducts of rectangular cross section whose walls are composed of acoustically different materials. The immediate problem solved here is the effect of a plane wave incident on two semi-infinite half-planes joined along a line. The problem is solved by the use of integral equations in which the admittance parameters are considered constant. This approach leads to an equation of the Wiener-Hopf type, solvable by a complex Fourier transform.

9. On the Diffusion of Tides into Permeable Rock, by G. F. Carrier and W. H. Munk.

10. Some Remarks on Radiation Conditions, by J. J. Stoker.

11. On the Theory of Scattering of Plane Waves by Soft Obstacles, by E. W. Montroll and J. M. Greenberg. We are here concerned with a mathematical model for the scattering medium and compare it with observed scattering patterns. Situations of this kind are found in physical chemistry where the arrangement of atoms in molecules is studied. The techniques apply equally well to the scattering of light from distant stars and are used to make inferences about the nature of interstellar dust. The paper reports the progress made on the problem of scattering of plane waves by soft particles for which the wavelength inside the scatterer does not differ much from that of the incident wave in the absence of the scatterer.

EDITOR'S NOTE: The price—$3.75—was omitted from the review of HADEKEL, "Hydraulic Systems and Equipment," Cambridge University Press, appearing in the August JOURNAL, p. 168.

12. Wave Propagation in Helical Compression Springs, by E. H. Lee. This is the formulation of a theory of spring surges both for elastic and inelastic coil-impact conditions. The mathematical techniques employed are similar to those used in the propagation of compression waves or of force doublets along an elastic spring, resulting in intermittent pulses of compression.

13. On the Wave Equation and the Equation of Euler-Poisson, by A. Weinstein. Results are given for a generalization of the classical wave equation which includes several cases of hyperbolic differential equations.

14. On Liénard's Differential Equation, by S. Lefschetz, discusses the solution of $\ddot{x} + \dot{x}\, dF(x)/dx + x = 0$ under certain, specialized conditions.

15. The Effect of Small Constraints on Natural Vibrations, by R. J. Duffin and A. Schild.

The financial support provided by the Carnegie Institute of Technology and the efforts of the McGraw-Hill Book Company have made these papers available to specialists interested in the progress along such lines of research. The net result of these combined efforts is a compendium on applied mathematics which abounds with fine mathematical tools and techniques. A large number of up-to-date references is appended to most papers and the printing of text and figures measures up to the high standards set by the preceding Symposium volumes. Without doubt, the book will be valuable to other applied mathematicians as well as to specialists working in the field of fluid dynamics.

CARL HAMMER and ROBERT P. COLEMAN

ACTIVE NETWORKS, by Vincent C. Rideout. 485 pages, diagrams, 15 × 23 cm. New York, Prentice-Hall, Inc., 1954. Price, $8.00.

The title of Professor Rideout's new book, *Active Networks,* is perhaps its most original feature. Actually, the substance of the book is electronics, with very little specialization evident. The title might well have been "Introduction to Electronics" or simply "Electronics"; but a variation from this overworked word is certainly attractive, even if it is nebulous and unrevealing when used as the title of a textbook. All of this is said to reveal a slight disappointment felt by the reviewer who expected to find a more specialized study of networks than was found.

Professor Rideout means by an "active network" nearly any electronic arrangement such as an amplifier or oscillator. Much of his book is devoted to discussions of the "elements" of the so-called active networks, and naturally these turn out to be all the various types of vacuum tubes. This is no news at all. In the author's defense it can be stated that there is included an up-to-date treatment of basic transistor circuits.

The author also feels a need for including some rather lengthy background material in order to show the utility of the electronic networks described. This leads to discussions of such subjects as noise and information theory or to a consideration of radar and computing applications. Needless to say, these departures greatly broaden the scope of the volume and force a brief and cursory presentation of all topics. Servomechanisms are treated in the space of four pages.

More positive comments may be made about Professor Rideout's book if we consider its intended purpose to be that of providing teaching material for a general course in electronics. Certainly an instructor would find the material gathered here adequate for a respectable introductory course in electronics. The student, perhaps majoring in some other field, would find here the necessary basic mathematical relations governing circuit operation, as well as a full list of references and a number of practice problems.

The index, which is so brief as to suggest that it was compiled as an afterthought, is less important in a text than in a reference book, so this may be overlooked. The publishers have no doubt had called to their attention that Fig. 5-14 is upside-down.

As taught, this was probably an interesting course. The selection of only the essential material descriptive of the various circuits together with a discussion of their uses undoubtedly avoided much of the tedium present in the more thorough treatises and yet gave the students some appreciation for electronic circuit work. C. W. HARGENS

AERODYNAMICS. SELECTED TOPICS IN THE LIGHT OF THEIR HISTORICAL DEVELOPMENT, by Theodore von Kármán. 203 pages, diagrams, illustrations, 16 × 24 cm. Ithaca, Cornell University Press, 1954. Price, $4.75.

This book might well have been titled "The Romance of Aerodynamics." In it, Dr. von Kármán has told in a most readable and fascinating manner the history of modern aerodynamics in words simple enough if not for the average layman, at least for the technically inclined but not aerodynamically specialized reader.

The work of the important contributors to the science has been discussed, evaluated and woven into the general pattern which is aerodynamics as it is understood and used today.

This little book should be on the "must" list of all aeronautical engineers and aerodynamicists as light reading when they want a refreshing break from their work-a-day tasks, and as educational reading for all those interested in the art and science of aerodynamics. R. S. BARNABY

OPTICAL IMAGE EVALUATION. NBS Circular 526. 289 pages, diagrams, illustrations, 16 × 24 cm. Washington, Government Printing Office, 1954. Price, $2.25.

This book is a collection of papers delivered at the Symposium on the Evaluation of Optical Imagery conducted by the National Bureau of Standards in cooperation with the Office of Naval Research.

As is well known, the evaluation of an optical system may be approached using either geometrical or physical optics. When the distribution of energy in the image is determined largely by aberrations, the geometrical approach usually suffices. However, when the distribution is dependent upon diffraction effects, the final evaluation can best be obtained through the application of physical optics. It is with the latter method that this book is mainly concerned. The designs of modern microscopes, certain astronomical telescopes, aerial cameras and quasi-optical radar systems are facilitated through the methods of physical optics.

The papers point out the many difficulties encountered in establishing a general acceptable quantitative measure of image quality. The material covered includes new developments in diffraction theory as well as the results of recent experiments. There are twenty papers representing the research being conducted both in the United States and abroad. The presentations are well written and the accounts of the discussions held afterwards enable the reader to gain a deeper insight into the problems involved.

F. Zernike, in a paper on "The Diffraction Theory of Aberrations," points out through the use of "circle polynomials" many interesting facts concerning the role of destructive interference in balancing out aberrations in lenses. He goes on to show that ". . . the physical properties of light waves are very favorable to the lens designer even if he ignores them altogether."

The sections dealing with the testing of a lens or system of lenses draws one's attention to the differences in the image evaluation problem when one uses photomultiplier tubes, photographic emulsions or the human eye-brain system.

While this book is by no means a "designer's handbook," it certainly deserves a place in the serious designer's library. Those scientists who employ high-resolution optical systems will find the reading useful and informative. J. B. DREW

CHEMISTRY OF THE DEFECT SOLID STATE, by A. L. G. Rees. Methuen's Monographs on Chemical Subjects. 136 pages, 11 × 17 cm. New York, John Wiley & Sons, Inc.; London, Methuen & Co., Ltd.; 1954. Price, $2.00.

This is a compact little book surveying the subject of point defects in solids. The introductory chapter discusses types and classification of defects and develops an interesting symbolic formulation for defect solids. This formulation is used throughout the text. Then follows a theoretical chapter covering statistical mechanics and a description of the quantum theory of the defect solid state. Chapter 3 discusses experimental methods used to give information on defects in solids. The next several chapters are devoted to chemical effects due to defects and are concerned with subjects such as oxidation, catalysis, adsorption and solution. The last chapter is titled "Outstanding Problems" and

is devoted to a two-page complaint regarding the paucity of our theoretical and experimental knowledge in the field of the defect solid state.

There is a list of 66 references and the book is adequately indexed.

Dr. Rees' book should be very valuable to a person with no background in the field and can serve as an excellent review for others.

LEONARD MULDAWER

FERROMAGNETIC DOMAINS, by K. H. Stewart. 176 pages, diagrams, plates, 14 × 22 cm. New York, Cambridge University Press, 1954. Price, $4.75.

The concept of domains in ferromagnetism was introduced by Weiss in 1907 to account for two rather contradictory facts in the behavior of these materials. On the one hand, relatively small applied fields produce enormous changes in magnetization. On the other, Curie temperatures for many ferromagnetics lie well above room temperature.

From the Curie temperature, an estimate may be made of the energy of interaction between the elementary spins. Expressed in terms of an equivalent magnetic field, this interaction energy is of the order of 10^7 gausses. This "field" is far in excess of the few hundred gausses required to saturate most "soft" magnetic materials. The mystery then is why such materials are not fully magnetized at all times, and why the puny fields developed in the laboratory are capable of causing the enormous changes in magnetization that are observed.

Weiss suggested that within small regions or domains, ferromagnetic materials are indeed constantly saturated. In any macroscopic piece, however, there are many domains whose directions of magnetization are more or less independent. The observed magnetization is the vector sum of the magnetizations of all the domains. For an unmagnetized piece, the magnetizations of the domains mutually cancel. The process of magnetization then consists in changing the direction of magnetization in the domains without appreciably influencing its magnitude.

For many years after this suggestion, the domain picture was accepted but vague. In the 1930's, the concept of magnetization by domains was used by Akulov to explain the magnetization curves of single crystals, and the groundwork was laid for the phenomenological theory of domain structure. Considerable progress was made during the 1930's by Becker, Bloch, Akulov, Landau and Lifschitz and others in extending the domain theory to cover more and more magnetic phenomena.

The most dramatic advances in domain theory, however, came with the work of the experimental physicists, beginning with Bitter in 1931, who observed the patterns formed by a suspension of ferromagnetic particles on the polished surface of the specimen. This technique, further developed by the Bell Telephone Laboratories group, including Elmore, Williams, Bozorth, and Nesbitt, made it possible to observe the domain patterns directly. Through the early 1940's, Néel built a detailed theory of domain arrangements which has been fully supported by subsequent powder pattern experiments.

There no longer exists any doubt as to the reality of ferromagnetic domains. The principles governing their structure and behavior in the presence of applied fields appear to be well established. Calculation of the magnetic properties of bulk material is essentially a problem in calculating domain arrangements. It seems fitting, therefore, that a whole book should now be devoted to a discussion of the theory of domains. K. H. Stewart has in recent years made significant contributions to the explanation of magnetization curves in terms of domain theory. He seems an excellent choice as author.

The arrangement of the material in this book is clear and logical. A short introductory chapter discusses the major notions involved. The various contributions to the free energy that determine the domain structure (magnetocrystalline anisotropy and magnetostriction) are given a chapter each. Then follow five chapters describing different facets of the results of the theory. The static arrangements of the domains are discussed, and theoretical patterns compared to those observed. One chapter is devoted to the walls between domains, their nature, size and energy. The effects of local stresses and inclusions in hindering the motions of the walls and so regulating permeabilities and coercive forces are given a chapter.

Two short chapters consider the time effects in the change of magnetization, and the disposal of the energy absorbed on going around the hysteresis loop.

The book is apparently intended as an exposition of the domain theory, on a level of medium difficulty. On this level, it is excellent. Much attention is given to calculations of energies of domain arrangements, etc., but for the most complicated portions of the mathematics the reader is referred to original papers. On the other hand, the statements of the theory are constantly compared to experimental observations, without, however, exhaustively reviewing the experimental literature. It is a good survey, and should serve as an introduction to the subject for the specialist.

It is rather too bad that the book is not more complete. Bozorth's tremendous "Ferromagnetism" contains an ample survey of the work that has been done in this field, among many others. There is no need to repeat that, especially since Stewart's book, although dated three years after Bozorth's, contains little new material. What is truly needed is a really detaileld treatment, in one book, of the theory and its experimental application. The reader should be able to derive the important equations without reference to other work, and should find sufficient experimental data to judge the validity of the theory. Neither of these conditions is met in the present book. Stewart has shown a real talent for making clear the important physical concepts behind the theory. Perhaps someday he will use this book as an outline for the larger, more complete work this should have been.

A. D. FRANKLIN

BOOK NOTES

THE BRITISH JOURNAL PHOTOGRAPHIC ALMANAC 1954, edited by Arthur J. Dalladay. 32 plates, 368 pages text plus 252 pages advertising, 13 × 19 cm. London, Henry Greenwood & Co., Ltd., 1954. Price, $2.00 (cardboard); $2.50 (cloth). Available from The British Book Centre, New York.

This almanac contains material of interest to all photographers. The professionals and specialists will be benefitted by the six papers on particular aspects of photography (there is one paper on "Colour and the Medical Photographer"); all camera enthusiasts, and most laymen, will enjoy the 32 photogravure plates which illustrate what can be done with a camera. In addition to these two sections, photographers will find news of the latest equipment, formulae for use in their work, sections on materials needed for various types of photographic work, and about forty pages of miscellaneous information such as exposure tables, optical data, hyperfocal distance, copyrighting, reproduction fees, passport photographs, storage of celluloid, etc. Not the least valuable of the many features of the almanac are the 252 pages of advertisements for all types of photographic and reproduction equipment.

FLUID MECHANICS, by R. L. Daugherty and A. C. Ingersoll. Fifth edition, 472 pages, diagrams, 16 × 24 cm. New York, McGraw-Hill Book Co., Inc., 1954. Price, $7.00.

The title of this work has been changed from *Hydraulics* to *Fluid Mechanics* in order to emphasize that the text is concerned with all kinds of fluids, not just water. Also, the new title indicates the advance from the purely empirical approach to one based on rational principles. The text is self-contained, since it has been lengthened to include subjects ordinarily left to outside reading. Also, the text has been designed—through the use of supplementary sections in smaller type—to be used in a brief course without destroying the continuity of the subject. The junior author, whose name appears on the text for the first time, is a civil engineer. The joint efforts of the two authors (the senior author is a mechanical engineer) have resulted in a blending of the two branches of engineering which should prove helpful not only to students, but to practicing engineers.

THE SCIENCE OF CHEMISTRY, by George W. Watt and Lewis F. Hatch. Second edition, 546 pages, illustrations, diagrams, 16 × 24 cm. New York, McGraw-Hill Book Co., Inc., 1954. Price, $5.50.

The second edition of this terminal text for nontechnical students brings the material up-to-date, including the latest research on artificial radioactivity and atomic energy, detergents, petroleum, hydrocarbon derivatives, medicinals and pharmaceuticals, as well as agricultural chemistry. The text includes organic chemistry, biological chemistry, agricultural and medicinal chemistry. Well illustrated and interestingly written, the second edition should prove popular for giving nontechnical students an appreciation of the accomplishments of chemistry, and of the social changes wrought through chemistry.

CALCULUS, by George E. F. Sherwood and Angus E. Taylor. Third edition, 579 pages, 16 × 24 cm. New York, Prentice-Hall, Inc., 1954. Price, $5.75.

The third edition of this popular calculus text includes new sections on simple harmonics, integral form of the remainder in Taylor's formula, and operations with power series. This edition also presents an improved discussion of Cauchy's principles of convergence and monotonic sequences. The many exercises have been carefully revised and graded.

HEAT TRANSMISSION, by William H. McAdams. Third edition, 532 pages, diagrams, 16 × 24 cm. New York, McGraw-Hill Book Co., Inc., 1954. Price, $8.50.

Prepared originally for practicing engineers and students of all phases of engineering, this well known text has been revised to include new information and to simplify some of the old material. One of the most important changes is the revision of Chapter IV on "Radiant-Heat Transmission," for it includes new charts for evaluating the emissivity due to sulfur dioxide, carbon monoxide and ammonia. Also, the carbon dioxide and water vapor charts have been expanded to permit estimation of radiation at rocket gas temperatures. New chapters cover natural convection, compact exchangers (packed and fluidized systems), and high-velocity flow of rarified gases.

SMITHSONIAN PHYSICAL TABLES, prepared by William Elmer Forsythe. Ninth revised edition, 827 pages, 15 × 23 cm. Washington, The Smithsonian Institution, 1954. Price, $9.00 (paper); $10.00 (cloth).

The ninth edition of this valuable work consists of 901 tables giving data of general interest to scientists and engineers, particularly those concerned with physics. The ninth edition is considerably larger than the previous edition because of the addition of several sections on atomic physics. The tables have been prepared by groups of experts and compiled from the best available sources. All those who used the previous editions should replace them with this latest edition.

HYDRAULIC RESEARCH IN THE UNITED STATES 1954, edited by Helen K. Middleton. National Bureau of Standards Publication 210. 193 pages, 20 × 26 cm. Washington, Government Printing Office, 1954. Price, $1.25.

This publication contains information compiled from reports by the various hydraulic and hydrologic laboratories in the United States and Canada. Reported projects include private, university and government supported research. A large number of the projects listed in this volume are reported for the first time. Projects are reported by title and carry a number which is kept throughout the project history. Other information includes the project sponsor, project correspondent, the nature of the project, a brief description, the present status, results and publications.

SUBMINIATURIZATION TECHNIQUES FOR LOW-FREQUENCY RECEIVERS. National Bureau of Standards Circular 545. 64 pages, illustrations, 20 × 26 cm. Washington, Government Printing Office, 1954. Price, $0.50.

This publication covers the second phase of a continuing program for the development of miniaturization techniques applicable to airborne military electronic equipment. The

work was carried out by the General Miniaturization Group, Engineering Electronics Section of NBS under support of the Bureau of Aeronautics, Department of the Navy. Earlier NBS work, reported in Office of Technical Services PB 100 949, covered miniaturization as applied to high-gain fixed-tuned intermediate-frequency strips in the very high-frequency band. This combines with the present developments to provide practical engineering treatment of a wide variety of electronic miniaturization problems over the radio frequency spectrum between 100 kilocycles and 100 megacycles.

ELEMENTS OF FOOD ENGINEERING, VOLUME II, by Milton E. Parker, in collaboration with E. S. Harvey and the late E. S. Stateler. 360 pages, diagrams, illustrations, 16 × 24 cm. New York, Reinhold Publishing Corp., 1954. Price, $8.50.

Volume II in this three-volume treatise on food engineering covers operations involved in assembling and preparing raw materials and the methods of converting the raw materials to marketable food products. Section I on assembly of raw materials deals with harvesting, transporting, receiving and materials handling of raw foods, including fruits, vegetables, milk, livestock and fish. There is also a chapter on separating (evaporating, drying, grading) various food products. Section II on the preparation of raw materials is concerned with the manifold problems of cleaning, separating (sorting, peeling, pitting, silking, dressing, filtering, rendering, etc.), disintegrating (cutting, grinding, homogenizing, spraying, etc.), and pumping. The last section of Volume II covers conversion of raw materials by mixing (with gases, liquids and solids), heating (by conduction, radiation and convection) and refrigerating (of liquids and solids). The text is well organized, profusely illustrated and adequately indexed. The work involved in compiling such a text—the first of its kind—is formidable and the authors are to be congratulated. The untimely death of Mr. Stateler and the retirement of Dr. Harvey have placed the brunt of the work of Volume II on Mr. Parker, who has done an admirable job. The three volumes should be of value to all food technologists, chemists and engineers connected with the vast food industry.

NUMERICAL TABLES OF NUCLEAR PHYSICS, by Charles Noël Martin. 258 pages, 16 × 25 cm. Paris, Gauthier-Villars, 1954. Price: $5.15 (unbound); $6.79 (bound).

These useful tables, written with both French and English texts, are a boon for the nuclear physicist who has lengthy calculations to make. Prepared by M. Martin, the tables are extensive, comprising six tables based on Weizsäcker's formula and eight tables of various nuclear phenomena (especially nuclear reactions and alpha radioactivity). Each of the fourteen tables is preceded by explanatory text material, with directions for use. The first six tables occupy about two-thirds of the book and include: two tables on Values of Atomic Masses; β-Transition Energies; α-Transition Energies; Binding Energies; and Terms of Weizsäcker's Formula. The remaining tables are: Nuclear Radii; Recoiling Effect on Calculations Relating to Thresholds; Multiplication Table Relating to Thresholds; Total and Kinetic α-Energies; Arc cos Factor in Gamow's Formula; Height of Coulomb Barrier; Geometrical Cross-Sections of Nuclei; and Conversion of m.amu into MeV. The extent of the utility of these tables may be surmised from the following quotation from Louis de Broglie's "Preface" to the work:

> So long as Nuclear Physicists have only the present semi-empirical formulae at their disposal—and the present conditions have a good chance to last for a pretty long lapse of time—M. Martin's tables will be most serviceable to all those who carry out researches in that field. We ought to compliment the author warmly on his arduous and most useful achievement.

ELEMENTS OF MATHEMATICS FOR RADIO, TELEVISION AND ELECTRONICS, by Bernhard Fischer and Herbert Jacobs. 569 pages, diagrams, 15 × 22 cm. New York, The Macmillan Company, 1954. Price, $5.40.

Prepared primarily as a classroom course in basic mathematics for students in radio, television and allied electronic fields, this book can be used for home study as well.

The text is divided into two parts. The first fifteen chapters constitute Part I, which is a review of the fundamentals of arithmetic and applied geometry, containing no algebra. The second part—eighteen chapters—includes negative numbers, literal equations, ratio and proportion, exponents, logarithms and a short discussion of sine and square waves. Both parts make use of problems related to radio, television and electronics, and so no mathematics is presented which does not apply to these subjects. The text is a practical one and should prove highly useful.

THE PHYSICS OF EXPERIMENTAL METHOD, by H. J. J. Braddick. 404 pages, diagrams, 15 × 22 cm. New York, John Wiley & Sons, Inc., 1954. Price, $7.00.

This text on the physics of experimental method will be welcomed since there are so few texts available. Three features of the new work make it of particular interest to the advanced student. First, it places great emphasis on the fundamental principles of measurement, observation and statistical analysis of errors. Second, it emphasizes the dependence of physical measurement on the proper design of instruments (including the properties of the materials used). Third, the scope of the book is such that it can be mastered by the average advanced student. Correct instrument design, precision measurements and careful experimentation are requisites in our modern manufacturing processes. This book helps the student to appreciate the exacting nature of experimentation and to become adept in its practice.

HANDBOOK OF HYDRAULICS, edited by Horace Williams King. Fourth edition, revised by Ernest F. Brater. 569 pages, tables, 13 × 20 cm. New York, McGraw-Hill Book Co., Inc., 1954. Price, $8.00.

The fourth revised edition of this standard handbook gives up-to-date, basic formulas and tables for the hydraulics engineer. Chapter 1 has been broadened to include other fluids besides water; new material on orifices and sluice gates has been added to Chapter 3. The material on flow over submerged weirs has been rewritten in the light of recent research. The users of this handbook will want to have the new edition, since the previous one was published in 1939, and much work has been done in the hydraulics field since then.

TO MEMBERS AND THOSE WHO KNOW THE FRANKLIN INSTITUTE

All of us associated with The Franklin Institute are gratified by the support given by its benefactors in the past. Without their generosity our privately endowed Institute would have been unable to serve industry, the professions, and the public as it has and should.

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CURRENT TOPICS

Shock Tube to Test Aircraft Models.—A shock tube with a section which bursts like a balloon to release a surge of air moving faster than sound is now testing aircraft models at the Massachusetts Institute of Technology. It was built and is being operated under the direction of Professors Raymond L. Bisplinghoff and H. Guyford Stever.

The "shock tube"—a kind of very fast-operating wind tunnel—is the property of the United States Air Force which financed its construction; the tube is now being used under a contract with the Air Research and Development Command, Wright Field, Dayton, Ohio.

This "shock tube" is actually a two-sided research tool, its designers explain. It can be used to produce a high-speed shock wave, which blasts aircraft models with the fury of an atom bomb. And it can also be used as a short-duration wind tunnel, to show the flow of air around an airplane model at speeds up to 1½ times that of sound. This includes the range of speeds—500 to 900 miles per hour, called transonic—in which the fastest piloted military aircraft are now flying.

The new equipment is part of Project Locus at M.I.T.—a study in the aeronautical engineering department of the effects of blasts on flying aircraft. How close to a bomb blast can a plane fly without structural damage? How must a plane be built to best withstand these tremendous forces? For the first time engineers can now by direct measurements confirm their theories of how an explosive shock wave lifts a moving aircraft.

The M.I.T. shock tube is actually a tube more than a foot square and 98 feet long made of ¾-in. steel plate; it weighs 13 tons. In the middle is a diaphragm section, where a sheet of film is inserted to divide the tube into two sections.

After the film is inserted a compressor builds up air pressure in one end of the tube, like a blown-up balloon. A pump can be used to reduce the pressure in the other end, where the test model sits waiting its blast. When all is ready a remote-control knife cuts the film—just as a knife could be used to burst a balloon—to unleash the explosion.

A violet shock wave is formed when the compressed air suddenly begins its rush through the broken film; in less than three hundredths of a second this shock speeds down the tube to strike its fury against the test model. Then, after this violent shock passes, the model for 40 thousandths of a second is in a steady high-speed air flow—the same kind of steady flow which can be achieved, for much longer periods, in conventional wind tunnels which are vastly more expensive to build and operate.

The fury of the shock wave, its speed, and the speed of the steady flow following the shock wave all depend on the amount of air pressure across the film when it breaks. These can be adjusted by properly controlling the shock tube before firing takes place.

With high-speed photography, electronically timed, the M.I.T. engineers can photograph the model at any instant during the test. In a series of tests such photographs can be made

to show all stages of a shock passing the model—or of the model in established high-speed air flow.

This M.I.T. shock tube is no toy to play with carelessly. Even at relatively low speeds the blast it makes would shake buildings and break windows were it not contained in the steel tube. Forces of 10 and 20 tons are common inside the tube, and the equipment is protected by elaborate hydraulic valves and safety interlocks.

A novel feature is a special cleaning cart which propells itself down the inside of the shock tube between tests, to sweep up, like a street sweeper, the debris of broken films exploded for each blast.

Microfilming Machine for Office Use.—A low-cost microfilming machine for office use which combines recording and reading in one compact, portable unit has been announced by Burroughs Corporation and Bell & Howell Company. The new device, manufactured by Bell & Howell and sold by Burroughs, has been named the Micro-Twin.

It was introduced by John S. Coleman, President of Burroughs, and Charles H. Percy, President of Bell & Howell, at a press conference in St. Louis prior to the opening of the Fifth Annual Office Machine and Equipment Exposition where the equipment was shown for the first time.

"Microfilming is becoming an increasingly important element of office systems," Mr. Coleman said. "It provides not only safe, convenient and space-saving storage of records, but is especially valuable as a time and money saving device for creating easily handled duplicate records to speed the processing of business data."

In commenting on the new device, Mr. Percy said: "Because of its compactness and low cost, we expect the Micro-Twin to create an entirely new and vast market for microfilm equipment. For the first time, all microfilming functions have been combined in a single 'table-top size' unit. Controls have been simplified. An inexperienced person can learn to operate the unit with only a few minutes instruction. The 'Twin' is the result of over 2 years of intensive market research and engineering development on the part of Burroughs and Bell & Howell."

Versatility of the Micro-Twin is exemplified by the range in size of documents it will accommodate. The Micro-Twin will record documents smaller than bank checks up to single sheets 11 inches wide and 3,700 feet long, photographing both sides. A system of mirrors is used to record the face and reverse sides at the same time. The machine will photograph documents intermixed in size just as fast as they can be fed into it.

At a 37 to 1 ratio, a 100-ft. roll of 16-mm film will record both sides of 14,000 checks or one side of 28,000 checks. A ratio of 24 to 1 also may be employed to utilize the full width of the film to record a single document. The dual purpose lens projects a life-sized image of the document on the reader.

The Micro-Twin is so light it may be carried easily by two persons. It has a rugged, light weight aluminum channel frame covered with plywood. The working surface is of malomine plastic which resists stains and burns. It measures 13½ in. high, 23 in. deep and 32 in. wide. Modern styling blends with up-to-date office furnishings. The reader screen is 8 by 11 in.

The new Micro-Twin also may be used to reproduce facsimiles of any filmed document without requiring the facilities of a dark room. Sensitized paper is exposed under the reader hood and can be developed under ordinary office light conditions. Within five

minutes after a facsimile has been requested, it can be delivered by the Micro-Twin operator.

Placing a 100-ft. roll in the camera for recording is as easy as loading a box camera. A simple knob control sets the lens. As the documents are photographed, the film is automatically indexed to set up a filing system and simplify locating documents on the reader. The film indexing meter is an exclusive Micro-Twin feature. As many as 999 locations may be indexed on a 100-ft. roll.

This 100-ft. roll, which takes up approximately the same space as a package of cigarettes, will record the average contents of a four-drawer filing cabinet.

Visible, automatic and audible safeguards on the control panel are a feature of the Micro-Twin. An alarm sounds if an operator tries to record with improperly loaded film and the machine will not operate if the lens is not in the recording position. Another alarm sounds and the recorder will not operate if one of the lamps in the machine burns out. An indicator shows how much film has been exposed. A lock prevents tampering or accidental film exposure.

High speed automatic feeding of documents is made possible with an "Acro-Feeder" attachment which features an adjustable micrometer control. This automatically stops the feeding when documents overlap or are thicker than the micrometer setting. An immobilizing switch permits feeding of documents of varying thicknesses without changing the micrometer setting.

Each document takes its own picture as it passes the camera lens. The leading edge of the document turns on the lights to expose the film and the lights turn off as the trailing edge passes the photographic area.

Resi-Twin Instrument to Control Vacuum Distillation.—Weiller Instruments Corporation (New York) has announced a new instrument built to control a vacuum distillation process. It is provided with eight sockets to take the plug connectors of eight resistance thermometer bulbs. Two of the bulbs are connected to a sensitive differential control. This control will maintain a constant temperature difference between two points of the still. A switch on the upper panel connects the indicator bridge either to the control or to the switches on the lower panel. In the first position, control and bridge operate from the same bulb; in the second position, any one of six bulbs may be connected to the bridge by the switches on the lower panel. There are also two range switches on the lower panel—one for the control and the other for the bridge. The instrument measures and controls to 400 deg. C.

New Portable Vibration Meter.—A new direct reading portable vibration meter—capable of measuring both displacement and acceleration—has been announced by the General Electric Company's Meter and Instrument Department.

Designated as type VHA it measures over a frequency range of 10–250 cps, acceleration ranges of 0–0.03, 0–0.1, 0–0.3, 0–1, 0–3, 0–10 G, and peak to peak displacement ranges of 0–3, 0–10, 0–30, 0–100 and 0–300 mils full scale, according to G-E engineers.

The new meter consists principally of a barium titanate accelerometer, which feeds through an electronic amplifier and a copper-oxide rectifier to an indicating microammeter. Unlike coil-type pick-up instruments, operation of this new meter is not affected by magnetic fields. Operating on common hearing aid batteries, the battery

voltage and calibration can be easily checked by an adjustment of the selector switches on top of the instrument.

The instrument weighs about 5 lb. and its over-all dimensions are 4 × 8 × 13¾ in. It is equipped with a pistol grip, trigger-type switch.

Private Telegraph Network Speeds Company Business.—Mathieson Chemical Corporation recently inaugurated a 5000-mile, high-speed private wire telegraph network to speed the flow of messages between its various offices and plants throughout the country. The system is the most advanced of its kind in the world, according to Western Union, which installed it.

The network covers an area of 15 states and interconnects 31 Mathieson plants and offices in 23 cities in the eastern, mid-western, southern and southwestern sections of the country. Immediate communication to any point on the wire circuit from any other station is possible. The wire system has a capacity of 24,000 words hourly, and thousands of messages a month will be transmitted.

Messages are prepared by operators in the form of perforated tape. The tape speeds through an automatic telegraph transmitter at a speed of 65 words a minute. At the destination the message is received automatically in page form ready for instant use. The new system also transmits orders in tabulated form.

Mathieson offices and plants served by the network are located in: Baltimore, New York, Brooklyn, Rochester, Niagara Falls, Philadelphia, Cleveland, Cincinnati, Chicago, St. Louis, Kansas City, Little Rock, New Orleans, Houston, Atlanta, Charlotte, Saltville, Va., Morgantown, W. Va., Brandenburg, Ky., Huntsville, Ala., McIntosh, Ala., Lake Charles, La., and Pasadena, Texas.

Research on Effects of Heat and Moisture on Cotton Fibers and Yarns.—Those whose work involves practical operations in which heat is applied to cotton products in the presence of air and moisture will find meaning in the following information reported by members of the Department of Agriculture's Southern Utilization Research Branch.

The scientists studied the strength and elongation of cotton fibers, as well as yarns, and correlated the fiber properties with the yarn properties—after heating fibers and yarns over a range of temperatures and conditions of moisture similar to those met commercially or in service; for example, in cotton-ginning, laundering, chemical-finishing, and in such products as conveyor belts and ironing board covers.

This is the first study reported over this range of conditions that includes cotton fibers, as well as yarns, and gives information on the fiber-yarn relationships after their degradation by heat and moisture simultaneously.

According to results (heating was from 2 to 128 hr. in an oven at 110°, 138°, and 162° C. in air representing relative humidities from 3% up to saturation): Loss in yarn strength is closely related to loss in fiber strength. Fibers and yarns are affected similarly —their strength and elongation are reduced by heat at the higher temperatures, regardless of the moisture present. Moisture plays a prominent role —for the least amount of degradation, it should be either very low or high enough to exclude air (at saturation point).

A simultaneous reduction of strength and elongation of fibers indicated that the degradation occurs through creating or intensifying weak points along the fiber. Studies of the mechanism of the reaction through viscosity determinations confirmed this.

Eight charts showing these effects are included in an article reporting the work ("Degradation of Cotton Fibers and Yarns by Heat and Moisture," in May *Textile Research Journal*, by R. S. Orr, L. C. Weiss, G. C. Humphreys, T. Mares, and J. N. Grant). A reprint may be obtained by writing the Southern Regional Research Laboratory, 2100 Robert E. Lee Boulevard, New Orleans, La.

New Eggs.—Currently, the Navy is testing two egg products which may mean that better eggs will soon be used by the fleet. The first is a "thermostabilized shell egg" which is expected to have 60 per cent longer storage life than the oil-dipped eggs now used. The second of the egg products is dried eggs treated with a special enzyme or baker's yeast removing the glucose which breaks down over a period of time producing an off-flavor.

Strontium-90 Self Luminous Markers.—Evaluation tests at the Naval Research Laboratory have shown safer, brighter, and longer lasting self-luminous markers may now be made for military equipment and personnel in a variety of colors. Instead of radium, the new markers use strontium-90 as the radioactive material to produce luminescence. The use of strontium-90 permits markers to be made in a variety of colors throughout the visible spectrum, with the possible exception of deep red, in contrast with the limited yellowish-green of radium. The "life" of a radioactive material is measured in terms of its half-life, or time required for its radioactivity to decay to half the original value; the half life of strontium-90 is 25 years, making possible markers with many years of useful life. There is also less radiation hazard from markers using strontium-90 than from those in which radium is used.

New Antihistamine for Acute Allergies.—Parke, Davis & Company (Detroit) has announced a new form of Ambodryl Hydrochloride, an antihistamine for treating a wide variety of allergies including hay fever, allergic rhinitis, asthma, urticaria, eczema and migraine. It is Steri-Vial Ambodryl Hydrochloride, an aqueous solution for parenteral use in acute allergic states "calling for immediate relief of an extremely distressed patient." Each cubic centimeter of the new drug contains 5 mg. Ambodryl Hydrochloride (bromodiphenhydramine hydrochloride), and physicians may inject the solution, as supplied in Steri-Vials, intravenously or intramuscularly.

Parke-Davis said intravenous injection of the antihistamine is preferred and results in rapid action when needed for relief of an acute allergic state. The company also explained that Ambodryl solution is valuable for the patient not responding quickly enough to oral forms of antihistamines.

Dosage of the Ambodryl solution depends on the type of allergic state being treated and its severity. Usual adult dosage is 1 to 2 cc. (5 to 10 mg.) intravenously.

"This dosage may be repeated in three hours, if needed, although usually doses are given once or twice daily," the company pointed out.

Single doses as high as 10 cc. have been given without toxic effects, Parke-Davis noted. However, a total daily divided dosage not to exceed 10 cc. (50 mg.) is recommended.

Steri-Vial Ambodryl Hydrochloride is supplied as individual 10-cc. rubber diaphragm-capped vials containing 5 mg. Ambodryl Hydrochloride per cc. in aqueous diluent.

Parke-Davis also supplies the antihistamine in capsule and elixir forms.